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OF

The Sugar Technologists' Association of India



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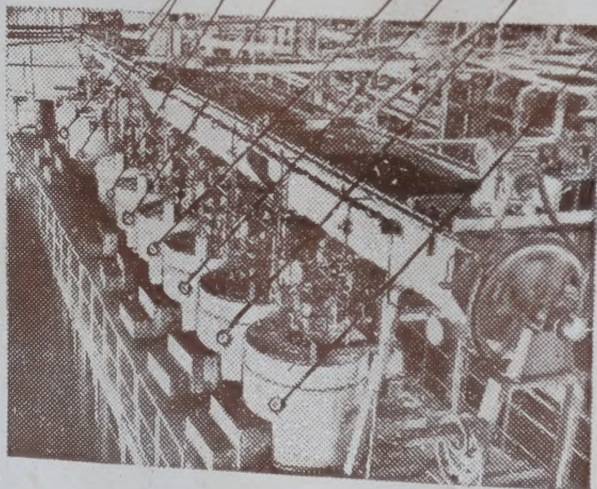
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CONTENTS

AGRICULTURE SECTION

1. A case Study of varietal, Maturity and Physiological aspects of sugarcane lodging by S. C. Sharma and G. S. C. Rao. 1
2. Effect of herbicides on weeds, yield and quality of autumn planted sugarcane (*Saccharum officinarum* L.) by Govindra Singh and P. P. Singh. 13
3. Assessment of TS-1, A Thick Cane Mutant by H. K. Shama Rao and R. S. Sachan and Mangal Singh. 23
4. Relative assessment of Co. J. 64 and Co. 1148 cane varieties for different agro-nomic and quality traits by R. S. Kanwar, P. S. Dhillon and S. K. Batta. 29
5. The Concept of rate of change of tissue Moisture and Nitrogen and their effect on sugar yield of sugarcane by Krishna Reddiar Perumal. 35
6. Leguminous intercrops for sugarcane by B. S. Nadagoudar, K. Kenchaiah, C. Shankaraiah, D. V. Krishna, G. V. Lokeshwarappa and R. Vijayamma. 47
7. Studies on the possibility of raising short duration crops of sugarcane by K. K. Prasadaraao, B. Gopalam, D. V. N. Raju and B. Jaganmohan Rao. 55
8. Effect of reatments with azotobacter cultures on the yield of sugarcane in varying agroclimatic conditions of Bihar by B. P. Sahi, N. Ahmad, M. Rai and N. L. Yadav. 63
9. Scale insects-A potential danger for sugar industry Eastern Uttar Pradesh by A. P. Gupta. 67
10. Is earthing up necessary for Adsali sugarcane. by J.D. Chougule and B.R. Patil. 75
11. Correlation and path coefficient analysis in early maturing genotypes in sugar-cane (*S. Offici Narum* L.) By Kanwar Singh, R. S. Sangwan, G. R. Sharma, A. D. Taneja, and M. S. Mooda. 81
12. Relative performance of different cane varieties in the low lying area (Khaddar) of Mawana Distt. Meerut. By A. K. Garg, J. S. Pandey and S. K. Taneja. 85

13. Effect of Bacterization with azotobacter and bacillus megaterium on the yield and Juice quality of sugarcane in calcareous soil by N. Ahmad, M. Rai and B.P. Sahi. 93
14. Studies on the effect of nitrogen and moisture regimes on yield and quality of sugarcane by M. Ramachandra Reddy, S. Chandrasekar Reddy, A. Venkatachari, H. L. Kulkarny. 99
15. Studies on the soil moisture regimes in sugarcane under shallow water table conditions of north India by S. K. Saini, P. P. Singh and K. Kumar. 123
16. Recent cane production Technology by R. S. Kanwar. 135

ENGINEERING & CHEMICAL ENGINEERING SECTION

1. Possibilities of reduction in power consumption of Indian sugar factories condensing system—A typical case by J. P. Mukherji & S. B. Bhad. 1
2. Conversion of Barometric Condensers to multijet condensers by H. L. Verma and V. K. Rohatgi. 5
3. A better condensing system by Anil C. Chatterjee and G. Kashinathan. 17
4. Introduction of Cooling Towers in Sugar Industries by K. K. Menon. 25
5. A new concept in regard to the manufacture of mill roller C. I. Scrapers by V. S. Joneja. 33
6. Study of headstock design by S. L. Kumar and S. Solaimuthu. 35
7. Balancing of the rotating machinery in sugar industry by V. Rama Rao. 41
8. Use of Aluminium tubes in sugar industry raw juice heaters by M. K. Swarup and S. K. Sanghal. 45
9. Installation of Resistance heater by A. P. Chinnaswamy, R. Lokan and R. Venugopal. 51

MANUFACTURING SECTION

1. Factory performance index (F. P. I.) by R. Lokan and A. P. Chinnaswamy. 1
2. A study of drop in purity in the boiling house by N. R. Tagore. 9
3. Utilization of $TF-S_3$ as a clarifying agent in gur industry. 13
4. A comparative study on the chemical characteristics of BO-70 variety of sugarcane obtained from different regions of east Uttar Pradesh and Bihar and their influence on the colour formation and clarification difficulties by S. C. Sharma and P. C. Johary. 19

5. Network Analysis—an aid in planning sugar industry projects by M. C. Gupta.	33
6. Studies on the use of flocculating agents during sugar cane juice clarification by sulphitation process by K. H. Rao and K. P. Sinha.	47
7. Inventory control and cost reduction in sugar industry by V. Singh.	59
8. Mini sugar industry—scope and prospects by B. L. Mittal.	65
9. Studies on the use of flocculating agents during sugar cane juice clarification part XI—settling studies with califloc—A by S. Bose, K. C. Gupta and S. K. Suri.	75
10. Mill Performance :—A comparative study for comparing the technical performance independent of sucrose content in cane by S. K. Gupta.	83
11. Prospects of reduction in cost of production of sugar in India—some practical aspects by S. K. Bajpai.	89
12. Reduction of water requirement in a cane sugar factory—A case study by Mangal Singh, V. M. Murugkar and S. J. Lagare.	103
13. Use of continuous centrifugal machine for curing low grade massecuites by M. N. Joshi and Raj Kumar.	113
14. Factors effecting total polyphenolic content in cane juice and their fate during clarification by S. C. Sharma, G. S. C. Rao and P. C. Johary.	123
15. Boiling house performance indicators by P. K. More.	137
16. Prevention of spontaneous combustion of molasses : A case study of the phenomena in two sugar factories in India by S. K. D. Agarwal, Km. Veena Gupta and J. K. Srivastava.	145
17. A new juice clarifier is born by B. L. Mittal.	167
18. A critical study of the causes for high mud volume formation in sulphitation sugar factories in India by K. H. Rao and K. P. Sinha.	171
19. Chemical composition and clarification characteristics of juices as affected by lodging of sugar cane by S. C. Sharma, P. C. Johary and G. S. C. Rao.	187
20. New method of compound imbibition part-I by S. T. Anjal, A. N. Maisale.	199
21. New method of compound imbibition Part—II by S. T. Anjal and A. B. Maisale.	207
22. Phosphatation of unfittered second carbonation cane juice—development of a new system of cane juice clarification for manufacture of superior quality sugar at reduced manufacturing costs Part-II—Factory Scale Trials by S. P. Misra.	215
23. Efficient working. of lime kiln—design, quality & operational aspects. by S. K. Bajpai.	231

24. Need for a proper formula for reduced mill extraction by J. C. Bhargava and I. S. Juneja. 245

CHEMICAL CONTROL & ANALYSIS

1. Part-I Spectrophotometric Method of Determination of sugar in traces by Mahendra Prasad, J. K. Srivastava and G. Ramanathan. 1
2. Abnormal behaviour of boiler water by S. T. Anjal and A. B. Maisale. 7

GENERAL & BY-PRODUCT

1. Working of Potash fertiliser plant at Walchandnagar, Utilising distillery effluent by Anil C. Chatterjee. 1
2. Studies on the utilization of methane by a coccus bacterium for the production of single cell protein by S. K. Misra and K. A. Prabhu. 17
3. Distinction between vacuum Pan and khandsari sugars by direct and alternating current polarographic studies based on variation in Anionic surface active substances by S. K. D. Agarwal and R. K. Gupta. 29
4. Uganda and its Sugar Industry by S. K. Chattopadhyay. 45
5. Utilization of Bagasse for the production of Microbial Protein by Miss Chhanda Sarkar and K. A. Prabhu. 53
6. Further Studies on the Treatment of ammonified distillery waste using aerobic processes to reduce the BOD, by C. B. Agnihotri and K. A. Prabhu. 65
7. Studies on froth fermentation of Molasses and its check up at Balrampur by B. B. Garg and B. K. Gupta. 81
8. Studies on better utilization of sulphitation press Mud by B. P. Sahi and Y. Rai. 105
9. Utilization of the By-products of sugar industry preparation of xylitol, a nutritive sweetener from bagasse by S. Bose, B. C. Gupta and S. K. Suri. 115
10. Production of High fructose corn syrup by streptomyces Sp. by Miss Mamta Bhatia & K. A. Prabhu. 123
11. Practical methods to check the downward trend in the factory sugar recovery with particular reference to Rajasthan conditions by N. Mukerji. 131
12. Dialysis of Caramels: Ultraviolet Spectrophotometric and chromatographic behavior of Components constituting Caramel by S. K. D. Agarwal and Km. Veena Gupta. 139
13. The Effects of yeast-extract and Exchange treatment of molasses on Kojic Acid Production by Resuspended fungal Mycelia by (Mrs) Pratima Bajpai, P. K. Agrawal & L. Viswanathan. 15

Agriculture Section

A CASE STUDY OF VARIETAL, MATURITY AND PHYSIOLOGICAL ASPECTS OF SUGARCANE LODGING

BY

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ABSTRACT

Number of parameters pertaining to sugarcane lodging have been evaluated during present case study. It has been observed that lodging of sugarcane exerts profound influence on cane yield and quality. The extent of losses, however, varied with variety in question. Results suggested inclination upto 60° do not exhibit any influence on cane yield or quality. The extent of purity losses due to lodging are found to be more pronounced during peak of maturity. The unusually high acid invertases activities in middle and top portions of stalk and low total chlorophyll content in leaf blades offered reasons for low sucrose per cent in juices of lodged canes.

Introduction

Lodging of sugarcane is perhaps one of the pertinent phenomenon in cane agriculture that deserves due attention. It is believed that poor root development (6) heavy nitrogen input (7) and strong winds (11, 13) induce cane crops to lodge. Unlike coastal regions of South India, in North Bihar agricultural practices such as propping to prevent lodging are not in common use. Cane crops in this area are, therefore, more liable to lodge. Incidentally, Marhowrah Sugar Factory of North Bihar experienced such situation when

60% cane crops of this factory's reserved area suffered heavy lodging as a result of late rains and high velocity winds. Since indications exist that lodging affects yield and quality (6, 12, 15) of cane, a detailed case study has been taken-up to investigate various parameters of chemical composition as influenced by lodging of sugarcane.

In the present study efforts have been made to study varietal response towards lodging, relationship of degree of inclination and sucrose % juice and inter-relationship of lodging and maturity phase of sugarcane. An

attempt has also been made to offer physiological explanation of lodging with the help of biochemical data.

Methods & Material

Different varieties of canes have been sampled (10 stalks/sample) in duplicate to assess extent of losses due to lodging. In every case comparison was made between perfectly erect canes of same variety from the same plots with that of completely lodged (90% inclination) cane. Degree of inclination was also maintained uniform (60%) in ratoon cane analyses where lodging was partial. In order to study magnitude of losses during peak of maturity period weekly analyses of BO. 34 (a mid-early variety) were carried out from mid November to 2nd week of February. To achieve this, one acre plot was selected of different varieties where both completely lodged and erect canes were available. Sampling method was same as in the case of varietal analyses. Weekly juice analyses (i. e. 4½ months after lodging) from the same plot (variety BO. 34) lodged and unlodged cane were sampled for biochemical and elemental analyses. Estimation of weight and juice analyses were done in accordance with standard methods. Assays of Acid invertase were carried out by the methods of Hatchetal (5) with an exception that reducing sugar content estimation was done by the Nelson and Somogyii (10) method. Chlorophylls were extracted in 80% (V/V) aqueous acetone and optical densities of aliquots were measured at 645 nm, 652 nm and 663 nm with Beckman Spectrophotometer (D. B. model). Total chlorophyll content was then calculated with Arnon's equatoon (2). After ethanolic

extraction total phenols were determined following the procedure of Swain and Hills(15). From wet digested samples of sheaths N, P and K were estimated colourimetrically and Ca content and ash % were determined after digestion of sheaths (7).

Results

Morphological Observations :

Heavy eastern winds during first week of October when cane crops were of 10-12 months old caused 60 to 90% inclination to the cane crop in Marhowrah area. The degree of inclination was more in cane crops where rows were in north-south direction and crops which were grown in east-west direction had partial lodging. It was also observed that lodging was severe in low lying areas and in fields where phosphate application was not in practice. Root system of erect clumps was found to be deep in relation to those who suffered lodging. Within 1½ months of lodging the stalks which were horizontal on the ground took upward turn and started growing vertically. At this time basal nodes of lodged clumps produced large number of set roots and side shoots. In fully lodged plants pronounced nodal bud sprouting and yellowing of leaves was also not uncommon. No such situation, however, occurred in crops where partial inclination took place.

Influence of Lodging on Fresh Weight of Cane :

A comparison of erect and standing canes of Co. 1148, BO. 34, BO. 70, BO. 84, CO.1158 indicated that lodging reduces the weight of both green tops and millable stalks, the effect being more pronounced in later ones. Degree

of weight reduction apparently varied from variety to variety. Decrease in weight of green tops was more pronounced in Co. 1148 (1.6 kg.) while weight loss in stalks was more in case of BO.70 (3.73 kg.). In comparison to ratoon, plant cane suffered more due to lodging. That is plant cane of variety CO. 1148 lost 1.6 kg. and 3.04 kg. weight in green

tops and stalks respectively whereas ratoon cane of same variety had reduction of only 0.7 kg. and 0.46 kg. It may be pointed out that in ratoon cane degree of inclination was 50% to 60 % while in plant cane lodging caused complete fall of cane. Yield of cane crop, therefore, seems to be less influenced by partial lodging.

Table-1

Effect of Lodging on the Weights of Green Tops and Millable Stalks*

Variety		Weight of 10 green tops Kg.	% reduction in weight	Weight of millable stalks kg.	% reduction in weight
CO. 1148	Standing	3.50	—	20.35	—
CO. 1148	Lodged	1.90	45.7	17.31	14.9
BO. 34	Standing	3.10	—	9.25	—
BO. 34	Lodged	2.82	9.1	6.95	24.9
BO. 84	Standing	2.7	—	10.83	—
BO. 84	Lodged	2.0	26.0	8.83	18.9
BO. 70	Standing	2.9	—	17.83	—
BO. 70	Lodged	2.6	10.3	21.56	20.9
				(% increase)	
CO. 1158	Standing (R)	3.16	—	14.78	—
CO. 1158	Lodged (R)	3.10	1.89	15.86	7.3
				(% increase)	
CO. 1148	Standing (R)	2.66	—	11.38	—
	Lodged (R)	2.59	2.7	13.82	21.4
				(% increase)	

R = Ratoon crop.

* Each figure is mean of 2 replicates.

Effect of Lodging on Quality of Plant Cane Crops :-

Table 2 summarises the comparative juice analysis data of erect and lodged cane of different varieties. It can be seen that brixes were always lower in lodged canes as compared to straight canes. The magnitude of difference among brix units varied from variety to variety. Maximum difference appeared in Bo. 70 and Bo. 34 (2.10 units) and lowest was in Co. 1158 (0.32 units). In agreement with this data

concomitant decrease in sucrose percent and purities of juice occurred in lodged canes resulting in low sugar % cane and poor expected recovery. In other words, varieties Bo. 34 and Bo. 70, which had greater difference in brixes, contained 18.75% and 16.5% less sugar in lodged canes as compared to erect ones. Irrespective of varieties, lodged canes possessed high reducing sugar content than the lodged ones.

Table-2**Influence of Lodging on Different Varieties of Sugarcane.***

Variety.	Brix.	Pol%.	Purity.	% R. S. sugar per 100° Bx.	Sugar%	Expected Recovery.
1.	2.	3.	4.	5.	6.	7.
BO. 34 Standing	17.27	13.93	80.66	3.67	10.45	7.97
„ Lodged.	15.17	11.84	78.50	3.89	8.80	6.68
BO. 70 Standing	17.32	13.88	81.65	3.06	10.41	8.11
„ Lodged.	15.42	12.00	77.82	4.73	8.93	6.66
BO. 74 Standing	20.50	17.81	86.88	3.02	13.52	10.78
„ Lodged.	20.10	16.89	80.05	4.85	12.79	9.99
BO. 76 Standing	19.50	16.49	84.56	2.62	12.47	10.19
„ Lodged.	19.20	16.18	84.77	2.86	12.23	9.98
BO. 84 Standing	16.50	13.57	82.24	3.45	10.17	8.27
„ Lodged.	15.70	12.42	79.11	3.50	9.26	7.39
BO. 88 Standing	17.46	14.29	81.84	40.98	10.74	8.67
„ Lodged.	16.66	13.28	79.71	5.22	9.94	7.93

Contd.

Variety.	Brix.	Pol %	Purity	% R. S. sugar per 100° Bx.	Sugar%	Expected Recovery
1.	2.	3.	4.	5.	6.	7.
Bo. 89 Standing	19.00	15.87	83.53	3.00	11.89	9.74
„ Lodged.	18.60	14.75	79.30	3.12	11.10	8.75
Co. 1158 Standing	17.32	14.85	85.74	2.62	11.18	9.28
„ Lodged.	17.00	14.48	85.18	3.27	10.89	9.01
Co. 1148 Standing	18.90	15.87	83.97	3.37	11.98	9.74
„ Lodged.	18.20	14.93	82.03	4.01	10.69	9.06

* Each figure represents mean of two replications.

Effect of Lodging on Ratoon Cane Crops :-

To observe effect of lodging on ratoon crop quality variety Co. 1158, Co. 1148, Bo. 70 have been analysed (Table 3.). It can be seen from the data that lodged and unlodged cane juices exhibited comparatively little variation in juice purities. This may be attributed to partial lodging in these crops.

Lodged ratoon canes of Co. 1148 had low

brixes, pol % and sugar % cane. In contrast to this, in variety Co. 115 and Bo 70 higher brixes pol % and sugar % cane were observed in juices of partially inclined canes. Juice purities were always lower in lodged canes but the expected recovery in Co. 1148 and Bo. 70 were found to be 0.03 and 0.24 units higher in lodged canes. No definite relationship was observed between juice purities and reducing sugar content in both lodged and erect canes of all the three varieties.

Table-3
Effect of Lodging on Ratoon Crop*

Variety.	Brix. %	Pol%	Purity	R. S. PPM/ 100 Bx.	% Yield	Sugar%
1.	2.	3.	4.	5.	6.	7.
Co. 1158 Standing	16.52	14.25	84.29	2.62	8.84	10.70
Co. 1158 Lodged	16.95	14.27	84.19	3.27	8.82	10.72
Co. 1148 Standing	17.01	14.20	83.48	2.42	8.53	10.67
Co. 1148 Lodged	16.85	13.98	83.02	2.15	8.56	10.49
Bo. 70 Standing	16.76	13.58	82.64	2.78	8.22	10.18
Bo. 70 Lodged	16.98	13.92	81.98	2.69	8.46	10.44

*Each figure mean of two replicates.

Influence of Lodging on Maturity of Cane :-

Juice analyses of mid-early variety (Bo. 34) for over 12 weeks period revealed the magnitude of losses in cane crops during peak of maturity period. The brixes of erect canes increased with the on set of maturity i.e. from middle of December (5th week). Same was found to be true in case of pol percent juice. In lodged canes brixes and sucrose percent juice either decreased or remained same throughout the three months period. Consequent to this, after 2nd week of December when variety attained peak of maturity significant variation in juice purities were observed between erect and lodged canes (at an average of 9.35 units) (Fig 1). In other sense,

during premature phase (till mid December) decrease in purity of mixed juice in lodged cane was 4.48% over erect cane, thereafter the decrease was as high as 12.73%. In concurrence with disparity of juice purities the reducing sugar percent in mixed juice was always higher in lodged cane in relation to erect ones. Fig. 2 shows that the reducing sugar percent was more or less same during November but with progress in age there was rapid decrease in reducing sugars in unlodged canes than that of lodged canes. Cummulatively weekly analyses data indicated that cane left in the field for over 4½ months after lodging does not build up sucrose and tend to accumulate more reducing sugars.

Table-4.

Analyses of Variety Bo. 34 for over 12 weeks to assess extent of losses due to lodging. *

Weeks.		Brix.	Pol%	Purity.	% Reducing sugar/100 ^o Brix.
1.		2.	3.	4.	5.
1st.	Standing	17.27	13.93	80.66	3.65
	Lodging.	15.17	11.84	78.05	3.89
2nd.	Standing	17.32	13.82	79.79	3.29
	Lodging	15.33	11.73	77.69	3.73
3rd.	Standing	17.34	13.42	77.39	3.69
	Lodging	13.44	11.52	74.61	4.34
4th	Standing	17.32	13.75	79.39	2.77
	Lodging	14.82	11.28	76.11	3.59
5th	Standing	18.07	14.81	81.96	2.66
	Lodging	13.97	10.57	75.66	3.87
6th	Standing	18.53	15.54	83.86	1.79
	Lodging	15.43	11.44	74.14	2.92
7th	Standing	18.34	14.78	80.59	2.67
	Lodging	14.78	10.48	70.91	3.59
8th	Standing	18.57	15.04	80.99	1.94
	Lodging	15.87	11.47	72.85	2.98
9th	Standing	18.61	15.24	81.89	1.67
	Lodging	15.32	11.10	72.32	2.72
10th	Standing	18.71	15.50	82.84	1.55
	Lodging	14.21	10.40	73.19	2.67

Contd.

Weeks.		Brix.	Pol%	Purity.	% Reducing sugar/100 ^o Brix.
1.		2.	3.	4.	5.
11th	Standing	18.13	15.24	84.06	1.77
	Lodging	14.98	11.29	75.37	2.74
12th	Standing	18.25	15.40	84.38	2.00
	Lodging	15.17	11.23	75.35	2.88

* Each figure represents mean of two replicates.

The relationship between cane acid invertase and lodging :—

As anticipated from juice analyses data, the soluble acid invertase levels were higher in lodged cane as compared to unlodged canes. There was about 20.58%, 42.70%, 3.13% increase in acid invertase activity in top, middle and bottom portions of lodged canes

over straight canes. More interesting feature was, significant acid invertase activity in middle portions of lodged canes where concave bend occurred due to lodging. Enzyme activity in this region was quite superior to invertase levels of apical portions of erect canes. Even in lodged cane the acid invertase activity in middle portions was 21.8% more than that of bottom portions.

Table-5
Effect of lodging on acid invertase activity in sugarcane.
Acid invertase activity. *

Position of stalk.	Erect.	Lodged.	% Increase in Lodged Canes.
Top	43.25	52.15	+ 20.58
Middle	48.12	33.72	+ 42.70
Bottom	36.12	37.25	+ 3.13

* Expressed as by of reducing sugars formed ml of juice/4 hours.

Chemical composition of cane as affected by lodging-

Total chlorophyll contents were considerably and significantly lower in lodged canes (80.61% lower than erect canes) Moisture % and total phenols of sheaths were found to be higher in lodged canes while former observation indicates maturity conditions of cane the later one suggests influence of stress on cane

plant. Similar to peatogenic infection and staling, the lodging might have induced phenolic production in cane (14). In relation to unlodged canes, sheaths of lodged canes, contained 21.43%, 110.53%, 75% less nitrogen, phosphate and CaO contents resulting in low ash percent in these canes. In contrast to all above result spotassium accumulation was 23.47% more in sheaths of lodged canes.

Table-6**Influence of lodging on composition of cane variety Bo. 34***

Constituents.	Erect.	Lodged cane.
Leaf blades (+ 4)		
Total chlorophylls mg/g.	2.98	1.65
Sheaths (+ 3 to + 6)		
Moisture %	71.24	77.76
Total polyphenols mg/g	2.1	3.72
Nitrogen % dry weight	1.53	1.26
Phosphate % dry weight	0.40	0.21
Potassium % dry wt.	0.98	1.21
CaO % dry weight.	0.70	0.40
Sulphate ash % dry wt.	9.9	7.2

*Each figure represents of mean of two replicates.

Discussion

Several workers (8,9,12 & 13) elucidated variety as a factor in sugarcane lodging. Verifying these observations present study suggests, since genetic factor is one of the important parameters that determines the detrimental effects of lodging there is need to evolve good number of varieties that are less prone to lodging. Besides the planting of cane in the direction of wind, taking care of all factors responsible for well established roots system is also an important aspect which can control lodging. The routine analyses data of variety Bo. 34 indicates the harmful effects of lodging prevalent in peak of crushing season viz. December to February. Severe low recovery problem experienced by Marhowrah Sugar Factory indentially coincided with the above fact. It may be recalled that the above factory had crushed 60% cane which was lodged. It is, therefore, obvious that to avoid severe loss in cane yields and low recovery problem accompanied by complications in processing, it is very essential to take all possible measures to prevalent cane crops from lodging. Ensuring of adequate phosphate fertilization to cane crop, propping either by bamboos or by trash twist method, are few such pertinent precautionary measures.

Different opinions exist regarding extent of sucrose losses with respect to degree of inclination of cane (4, 5). Results of the present study clearly suggest that irrespective of variety, 90° inclination of cane results in rapid decrease in cane quality while inclination upto 60° renders no appreciable effect on juice

quality or on tonnage. Studies carried out in Bihar by Khanna (12) showed lodging in sugarcane is a root phenomenon. Low P_2O_5 content in sheaths showed possibility of poor root development in lodged canes. The ratoon cane, which is supposed to possess well developed root system exhibited partial lodging as compared to plant crop.

Unusually high acid invertase activities in middle portions of lodged cane indicates enhanced internodal extension and growth in these regions. High acid invertase levels in lodged cane verifies the observation of Glazziou *et al* (15) and other workers (9) and gives following physiological explanation of low sucrose % in middle stalks of lodged cane. When cane stalks fall horizontally on the ground the plant loses apical dominance, due to this initiation of side shoots and nodal and bud sprouting takes place. To regain apical dominance and also to respond "photo-tropic effect", the upper middle portions of cane takes concave curve and grows vertically. Additional energy required for these growth process is obtained through sucrose after inversion catalysed by acid invertase. High reducing matter content in lodged cane juices encountered during this study further supports the above contention. Low sucrose % in juice can also be attributed to low photosynthetic efficiency presumed to prevail because of enormously low chlorophyll content in lodged cane leaves. The sheath analysis data suggests that lodging either curtailed nutrient uptake or induced quick migration of elements to other parts. However, more detailed studies are needed in this regard.

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JUICE PURITIES OF ERRECT & LODGED CANES AS FUNCTION OF TIME

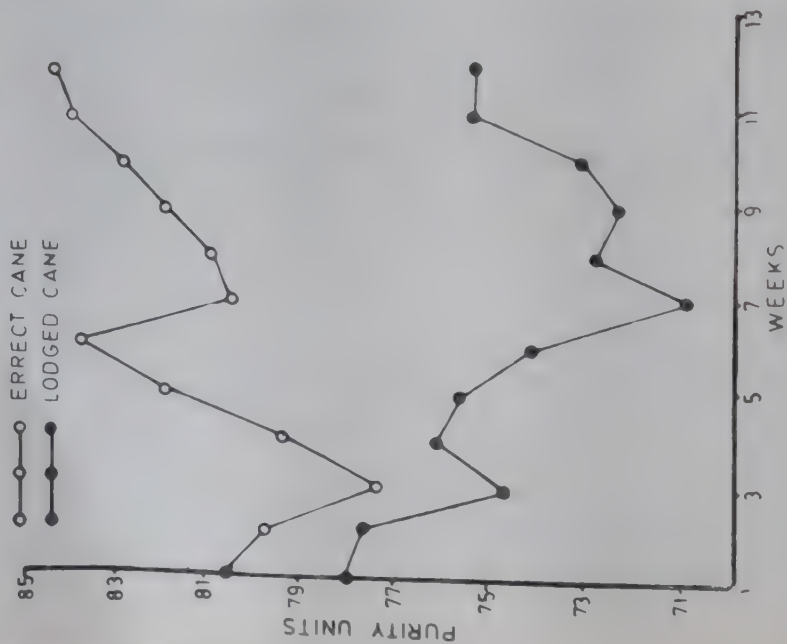


Fig. 1

REDUCING SUGAR CONTENT IN ERRECT & LODGED CANES AS FUNCTION OF TIME

○ ERRECT CANE
● LODGED CANE

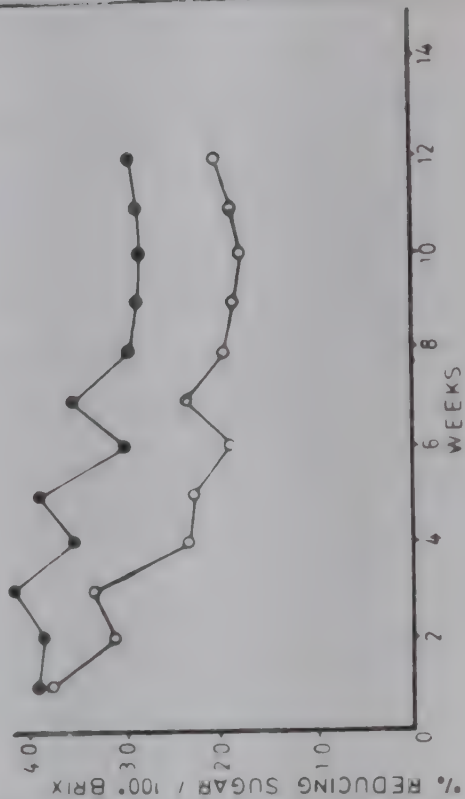


Fig. 2

EFFECT OF HERBICIDES ON WEEDS, YIELD AND QUALITY OF AUTUMN PLANTED SUGARCANE (*SICCHARUM OFFICINARUM* L.)

By

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ABSTRACT

*Sugarcane yields were reduced by 46.7 and 93.7% due to the infestation of weeds in 1973-74 & 1974-75, respectively. Among winter season weeds the major population was of *Physalis minima* L. and *Chenopodium album* L. The major weeds of rainy season were *Echinochloa* spp. and *Sorghum halepense*. Application of 2, 4-D @ 1 kg. ai/ha, 30 and 60 days after planting, 2, 4-D + dalapan (@ 1 + 2.5 kg. ai/ha), pre-emergence application of simazine @ 2 kg., atrazine @ 2 kg., terbacil @ 1.5 kg. ai/ha and directed spray of paraquat @ 0.5 kg. ai/ha, 30 and 60 days after planting were found effective in controlling the weeds of autumn planted cane depending upon the weed species present in the field.*

Autumn planted crop of sugarcane becomes infested with a wide spectrum of weeds which come up even earlier than the emergence of sugarcane seedlings and field gets covered completely with the weeds smothering the crop. The cane yield losses due to weeds have been reported upto an extent of 14-75% (Arakeri, 1953, Patro and Tosh, 1973, Singh and Singh 1977 Gopalakrishna, 1977). The extent of loss depends upon the nature, intensity of weeds and the stage of crop growth infested with weeds. Autumn planted sugarcane requires an initial weedfree period of about 120 days (Singh and Singh, 1977) to avoid the losses due to weed competition. Competition due to weeds during this period

may be avoided either by the use of mechanical or chemical methods of weed control depending upon the availability of resources and technology. A number of herbicides have been used for weed control in sugarcane with varying degree of success. The present study was aimed at finding out the effectiveness of some herbicides in controlling the weeds of autumn planted sugarcane.

Materials and Methods

A field trial was conducted during 1973-74 and 1974-75 at the Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar on a silty clay loam soil, rich in organic matter, available phos-

phorus and potassium, having near neutral pH. The experiment was laid out in a randomized block design with 14 treatments (Table 2) 4 replications. Co 1158 variety of sugarcane was planted on 25 October 1972 and 1 November 1973 in furrows 90 cm apart. An uniform application of 60 kg. N/ha was made at the time of planting and 60 kg. N/ha was applied as top dressing. Herbicides were applied by foot sprayer in aqueous solution at the rate of 1000 litres per hectare. 2, 4-D (alone) was applied 30 and 60 days after planting. Where 2, 4-D was combined with other herbicides, it was applied only once, 30 days after planting. Dalapan was applied in March as directed spray. Two applications of paraquat were made as directed spray, with hooded nozzle, 30 and 60 days after planting. Simazine (alone), atrazine, terbacil, asulam and a tank mixture of asulam+acril-D were applied as pre-emergence treatments. In case of treatment where simazine was followed by 2, 4-D, simazine was applied in the month of February in between the rows of sugarcane. In one of the treatments where split application of simazine was made, the first application was pre-emergence and the second application was made in February, in between the rows of sugarcane. Hoeing was kept as a standard treatment which is the general practice adopted by the farmers in the area. This treatment was effected with the help of spade and in all three hoeings were done after giving three irrigations. Three irrigations were common to all the treatments. Weedfree treatment was maintained by removing weeds manually with least disturbance to the soil. Weeds in each plot were sampled randomly at 2 places with the help of 0.25 m² quadrat and dried in hot

air oven to record dry matter yield. Weed species and their intensities were recorded in the weedy control plots. Sugarcane juice analysis was done by Horne's dry lead method as described by Spencer and Meade (1955).

Results and Discussion

Weed species, intensity and growth

Weed species and their intensity recorded in weedy plot at two stages are given in Table 1. Weed species which emerged during winter season after planting the cane were broad leaved annuals, *Cyperus rotundus*, *Cirsium irvense* and *Sorghum halepense*. On an average annual broad leaved and perennial weeds constituted more than 83 and 16% of the total weed population respectively in winter season. *Physalis minima* and *Chenopodium album* were the pre-dominant species among annual broad leaved weeds while *Sorghum halepense* and *Cyperus rotundus* were the most pre-dominant among perennial weeds. During rainy season, the major weed population was of grasses, pre-dominantly *Echinochloa spp.* and *Sorghum halepense*. The population of rainy season broad leaved weeds was negligible. The intensity of *Sorghum halepense* was much higher in 1974-75 as compared to 1973-74.

It was observed that all the broad leaved weeds of winter season were effectively controlled by the use of 2, 4-D except *Physalis minima*. Initially, there was some effect of 2, 4-D on this weed but it recovered slowly and slowly. Dalapon and terbacil were found to be quite promising against *Sorghum halepense* and *Cyperus rotundus*. Growth of *Cyperus rotundus* was checked by 2, 4-D.

Two applications of 2, 4 - D either at 1 or 3 kg. ai/ha, 30 and 60 days after planting was quite effective in suppressing the sprouting of *Cyperus rotundus* thereby avoiding the competition with the crop during early stages of growth. Similar observations were recorded on broadleaved weeds. Paraquat had good control of those annual weeds which emerged between the rows of sugarcane but perennial weeds were affected temporarily and sprouted after a week of application. Some effect of assulam was also observed on *Sorghum halepense* but other weeds of winter season were not affected much. Pre-emergence application of simazine and atrazine each at the rate of 2 kg. ai/ha was very effective for the control of annual weeds of winter season as well as they had their residual effect on the annual rainy season weeds also. Application of simazine, either at the rate of 1 or 2 kg. ai/ha, in the month of February had no effect on weeds. All the herbicides reduced weed population and dry weight of weeds as compared to weedy check (Table 2). Dry weight of weeds was considerably reduced by 2, 4-D, simazine, atrazine, paraquat and terbacil. Dry weight of weeds recorded during rainy season was closely related with the degree of weed control achieved in winter season. In those treatments, where good control of weeds was achieved in winter season, relatively less dry matter was produced in such treatments during the rainy season. This was due to the fact that at the time when rainy season weeds started coming up the crop developed closed canopy thereby suppressing the growth of such weeds by shading. In general the overall weed population and dry matter of weeds was higher in 1974-75 as compared to

1973-74. Application of 2, 4-D + dalapon resulted in the better check of winter season weeds as well as *Sorghum halepense* which contributed much towards the dry matter production by total weeds during rainy season. Hoeing was effective for the control of annual weeds of winter season but a large number of weeds emerged in this treatment during rainy season as compared to any other treatment.

Crop growth was recorded in terms of its germination, number of shoots and millable canes produced per hectare (Table 2 and 3). Germination of sugarcane was not affected by any of the treatments. In 1973-74, non-significant differences were observed amongst the number of shoots produced by different treatment. 2, 4-D 3 kg., simazine 2 kg., atrazine 2 kg., 2, 4 - D + dalapon (1+2.5 kg.), terbacil 1.5 kg. ai/ha and hoeing produced significantly more number of shoots per hectare as compared to weedy check in 1974-75. Shoot production in 2, 4 - D + dalapon (1+2.5 kg.) and simazine (2 kg.) treatments was comparable with that of weedfree treatment. In general, less number of shoots per hectare were produced in different treatments during 1974-75 as compared to 1973-74 due to high intensity of weeds and severe competition in this year.

Millable cane production was significantly increased in all the treatments as compared to weedy check, except in case of asulam in 1973-74. The number of millable canes produced per hectare by 2, 4 D (2 & 3 kg.), simazine (2 kg.), atrazine (2 kg.), 2, 4-D + dalapon (1+2.5 kg.), paraquat (1 kg.) and terbacil (1kg.) was considerably higher than other treatments

and comparable with hoeing treatment in 1973-74. In 1974-75, the number of millable cane production was quite low as compared to that of 1973-74, this was mainly due to the poor shoot production because of heavy crop weed competition during this year. The millable cane production in this year of simazine (2 kg.) atrazine (2 kg.) and 2, 4-D + dalapon (1 + 2.5 kg.) was comparable with that of hoeing treatment. Among herbicidal treatments, the highest number of millable canes per hectare was produced by terbacil and 2, 4-D + dalapon treatments in 1973-74 and 1974-75, respectively, which were comparable with that of weed free treatment which gave maximum number of millable canes per hectare.

Yield and Quality

Cane yield was affected significantly due to the different treatments (Table 3). All the treatments produced significantly more cane yields as compared to weedy check in both the years except simazine + simazine (1 + 1 kg.) and asulam (3 kg.) in 1973-74. 2, 4-D (1 and 3 kg.), atrazine (2 kg.), paraquat (0.5 kg.), terbacil (1.5 kg.) and weedfree treatments produced significantly more cane yields than hoeing in 1973-74. In 1974-75, cane yields were considerably low in all the treatments except weedfree, which indicated high degree of crop-weed competition in this year due to high intensity of weeds. Cane yields produced by atrazine (2 kg.), simazine (2 kg.), 2, 4-D + dalapon (1 + 2.5 kg.) and terbacil (1.5 kg.) were comparable to the cane yields produced by hoeing treatment. In both the years, the highest cane yields were obtained from the weedfree treatment and the yields obtained from hoeing

treatment were always lower than the weedfree treatment. The differences in the cane yields produced by 2, 4-D (1 and 3 kg.), atrazine (2 kg.), simazine (2 kg.) and terbacil (1 kg.) were not much in 1973-74 and these treatments were equally effective. In 1974-75, the cane yields from 2, 4-D + dalapon (1 + 2.5 kg.) treatment was at par with that weedfree treatment and simazine and atrazine each at 2 kg. ai/ha were also equally effective.

On an average cane yield reduction in weedy check plot was 46.7 and 93.7% in 1973-74 and 1974-75, respectively, when compared with weedfree treatment. Hoeing treatment never yielded at par with weedfree treatment and on an average there was 29.6% less yield in hoeing treatment plot as compared to weedfree plot. It indicated that the usual practice of hoeing is not effective in eliminating the crop-weed competition in sugarcane at a desired level. This is due to the fact that the weeds present within the rows were not controlled effectively, many of the perennial weeds sprouted immediately, in wet conditions they re-established and also more and more weeds germinated after each hoeing. Similar observations were recorded by Singh and Singh, 1977, in autumn planted cane.

Sugar yield per hectare followed the same trend as cane yield (Table 3). The average maximum sugar yield of 10.6 t/ha was observed from weedfree treatment and the average lowest was 3.2 t/ha from the weedy check. Sucrose in cane juice was not affected due to the different treatments. The variation in sugar yield due to different treatment was not due to the variation of sucrose percentage in cane juice but because of the effect on cane yields.

Table-1.
Weed Species and Their Intensity

Name	No. of Weeds/m ²		Average intensity (%)
	1973-74	1974-75	
Winter Season¹			
<i>Anaallis arvensis</i> L.	16	31	5.70
<i>Cirsium arvense</i>	8	6	1.70
<i>Chenopodium album</i> L.	54	84	16.75
<i>Cyperus rotundus</i> L.	38	52	10.92
<i>Fumaria parviflora</i> Lamk	9	21	3.64
<i>Melilotus alba</i> Desr	30	9	4.73
<i>Physalis minima</i> L.	105	162	32.40
<i>Solanum nigrum</i> L.	23	53	9.83
<i>Sorghum halepense</i> (L.) Persoon	7	85	11.17
<i>Visia sativa</i> L.	9	17	3.16
Rainy Season²			
<i>Brachiaria ramosa</i> L.	71	67	13.70
<i>Chloris barbata</i> Sw.	23	37	5.96
<i>Chorchorus acutangulus</i> Lamk.	16	14	2.98
<i>Cyperus rotundus</i> L.	31	39	6.95
<i>Dactyloctenium aegypticum</i> (L.) Beauvois	19	40	5.86
<i>Digitaria sanguinalis</i> (L.) Scop.	23	15	3.78
<i>Echinoehloa</i> spp. L.	120	157	27.51
<i>Eleusine indica</i> (L.) Gaertn.	13	30	4.27
<i>Paspalum</i> spp. L.	27	39	6.55
<i>Phyllanthus niruri</i> L.	9	14	2.28
<i>Sorghum halepense</i> (L.) Persoon	21	182	20.16

¹ Winter season : Observations on 1 January 1973 & 10 January 1974.

² Rainy season : Observations on 10 July 1973 & 16 July 1974.

Table-2
Effect of different treatment on the growth of sugarcane and weeds,

Treatment	Rate kg. ai/ha	Germination %		No. of shoots '000/ha			Dry matter of weeds g/m ²			
		1973-74 30DAP*	1974-75 45DAP	1973-74 275 DAP	1974-75 280 DAP	1974-75	1973-74		1974-75	
							WS	*RS	WS	RS
2, 4-D	1	33.2	41.3	206	121	15.7	25.6		42.8	225
2, 4-D	3	35.9	39.1	210	162	1.2	15.3		52.8	210
2, 4-D + Simazine	1+2	34.6	37.2	214	132	30.2	108.7		55.7	240
Simazine	2	33.3	38.3	217	221	18.4	69.8		26.2	120
Simazine + Simazine	1+1	30.7	39.7	196	152	26.4	122.5		49.7	246
Atrazine	2	33.4	40.5	197	189	20.3	56.2		31.7	130
2, 4-D + Dalapon	1+2.5	32.6	40.6	221	235	24.5	115.6		10.5	95
Paraquat	0.5	30.7	41.2	211	115	4.5	110.1		47.8	225
Terbacil	1.5	31.2	37.6	195	189	8.8	117.2		39.8	175
Asulam	3	30.8	39.4	216	131	85.1	145.8		104.8	301
Asulam + Atril - D	3+1	32.8	37.8	229	127	79.0	135.9		111.7	315
Hoing	-	31.2	36.9	205	215	9.0	226.0		23.8	272

Contd.

Effect of Herbicides

Treatment	Rate kg. ai/ha	Germination %		No. of shoots '000/ha			Dry matter of weeds g/m ²		
		1973-74	1974-75	1973-74	1974-75	1974-75	1973-74	1974-75	1974-75
		30 DAP*	45 DAP	275DAP	280 DAP		**WS	***RS	WS RS
Weedy	—	33.4	38.5	204	121		146	325.2	189.8 480
Weedfree	—	32.9	39.7	226	205		—	—	—
SE m ±		1.5	2.6	13	12				
CD at 5%		NS	NS	NS	35				

* DAP = Days after planting

** WS = Winter season : Observations on 1 January 1973 and 10 January 1974

*** Rs = Rainy season : Observations on 10 July, 1973 and 16 July 1974

Table-3

Effect of different treatments on the yield and quality of sugarcane

Treatment	Rate kg. ai/ha	No. of millable canes '000/ha at harvest	Cane yield t/ha		Sugar yield t/ha		Sucrose in juice %	
			1973-74	1974-75	1973-74	1974-75	1973-74	1974-75
2, 4-D	1	98	96.4	45.0	8.9	3.8	14.2	13.3
2, 4-D	3	96	92.9	52.7	9.4	4.8	15.1	13.9
2, 4-D + Simazine	1+2	83	79.1	40.2	6.9	3.4	13.8	13.5
Simazine	2	89	86.2	94.1	6.8	8.7	14.5	14.1
Simazine + Simazine	1+1	76	66.4	46.3	6.4	4.0	15.2	13.2
Atrazine	2	97	92.4	86.2	8.2	6.2	14.0	12.0
2, 4-D + Dalapon	1+2.5	90	80.3	114.6	7.9	10.1	13.8	13.6
Paraquat	0.5	98	90.7	44.3	8.8	3.8	13.1	13.4
Terbacil	1.5	102	96.7	78.0	8.8	7.3	14.5	14.2
Asulam	3	66	60.7	31.0	6.6	2.8	14.6	14.0
Asulam + Actril-D	3+1	79	74.0	30.9	7.1	2.5	14.1	13.0
Hoeing		89	80.5	84.0	8.1	7.7	15.0	14.0
Weedy	—	65	58.2	7.9	5.8	0.7	14.9	13.3
Weedfree	—	108	109.2	125.2	10.7	10.6	14.6	13.2
SE m $\pm$		3	3.4	6.5	0.5	0.6	0.7	0.6
CD at 5%		10	9.6	18.5	1.4	1.7	NS	NS

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ASSESSMENT OF TS-1, A THICK CANE MUTANT

By

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ABSTRACT

A true breeding thick cane mutant TS-1, induced by radiations, was obtained in variety Co-419. TS-1 was found to be superior to Co-419 with respect to cane size, weight, yield and juice quality. The thick canes of TS-1 were found to be solid even at 14 months age and so also their ratoons. The tillering habit of TS-1 has a definite advantage over other varieties with respect to easy intercultural field operations. TS-1 is now being tested under various agroclimatic zones in Karnataka, Maharashtra and U. P.

Introduction

An attempt was made to improve sugar cane through mutation breeding. Shama Rao et al (1977) have already reported obtaining of a true breeding thick cane mutant designated as TS-1. This was achieved through irradiation of bud sets of var. Co-419 with Co 60 gamma rays.

The present report highlights some of the agronomically useful characters of TS-1, as compared to its original parental variety.

Experimental

Experiments were conducted both at BARC (Trombay) and KIAAR (Sameerwadi) simultaneously to assess the performance of TS-1 and Co-419. For this purpose, single bud sets were planted at a distance of 45 cm within a row of 10 meter length. There were 10 such rows at 90 cm apart, the plot size being 90 sq. metre per variety.

Pooled data obtained on germination,

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millable canes and their yield is presented in Table—1. The percentage of canes falling under various girths (diameter) is presented in Table--2. The percentage of plants falling under various frequencies of shoots and millable canes at maturity is presented in Fig. 1. At KIAAR, TS-1 and Co-419 were analysed for the juice at 10 and 12 months age. The juice obtained from a laboratory crusher was analysed for brix, pol. purity and c.c.s.%, which is presented in Table—3.

Results and Discussion

The prime factors contributing towards cane yield are better germination, higher number of millable canes per unit area and increased cane weight. From the qualitative point of view the juice should be of higher purity with enhanced sucrose content.

In the case of the thick cane mutant, TS-1, it may be noted that majority of shoots produced turned into millable canes unlike in the parental type Co-419 (Fig. 1).

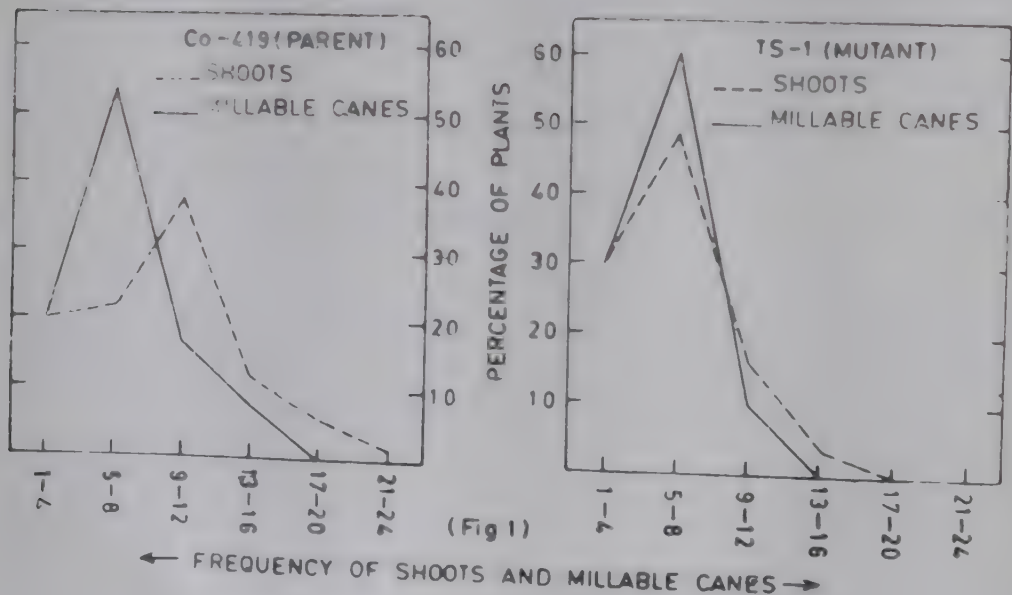


Table-1**Various attributes of Co-419 & TS-1**

Characters	Parent	Mutant
	Co-419	TS-1
1. No. of buds planted/plot	220	220
2. No. of buds germinated	188	194
3. Germination (%)	85.2	88.2
4. No. of millable canes/plot at 12 months age	1184	989
5. Average no. of millable canes/clump	6.3	5.1
6. Cane yield/plot (90 sq. meter) in Kg.	1480	2275
7. Estimated yield/acre (Metric Tonnes)	66.0	101.0
8. Average cane wt. (Kg)	1.25	2.30

Table-2**Percentage of canes under various girth (diameter)**

Cane girth (cm)	Parent	Mutant
	Co-419	TS-1
3.0 — 3.4	81.0	0.0
3.5 — 3.9	19.0	0.0
4.0 — 4.4	0.0	3.0
4.5 — 4.9	0.0	23.0
5.0 — 5.4	0.0	64.0
5.5 — 5.9	0.0	10.0

Table-3

Juice analysis in Co-419 and TS-1

Analysis	10 months age		12 months age	
	Co-419	TS-1	Co-419	TS-1
1. Brix	16.90	18.20	21.62	22.76
2. Pol	14.84	15.72	19.01	20.39
3. Purity	87.82	88.37	88.40	89.50
4. C. C. S. (%)	10.23	10.75	13.11	14.16

N. B. : C. C. S. (%) = $[S - (B - S) 0.4] 0.73$.

The millable canes per clump were slightly lower in TS-1 as compared to Co-419 (Table-1) and thereby also the total number of millable canes per unit area. However, due to the increased cane girth (Table-2) and weight (Table-1) in TS-1 the cane yield was significantly more than that of Co-419.

It was further interesting to note that in TS-1, both at 10 and 12 months age, the juice was superior to that of Co-419 with respect to brix, pol, purity and the expected percentage recovery of commercial cane sugar (Table-3). Another salient feature observed was that even in 14 months old canes of TS-1, the thick canes were solid with no symptoms of hollowness in them.

The tillering habit of TS-1, viz, "like that of the spreadout wings of a male peacock",

has been found to be helpful (by a specific method of plantating) in maintaining clear passage between rows which facilitate easy earthing up and other cultural operations. The ratoons of TS-1 have also been found to breed true. The encouraging results obtained so far with TS-1 has prompted further testing of the same under different agroclimatic conditions.

Presently, preliminary spacing cum manual trials with TS-1 is being conducted at three locations in Maharashtra and one in U. P., besides Sameerwadi and Trombay.

Acknowledgement

The authors are grateful to B.A.R.C. and the Godavari Sugar Mills Ltd. (Bombay) for encouraging this collaborative research project on sugarcane mutation breeding.

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RELATIVE ASSESSMENT OF CO. J. 64 AND CO. 1148 CANE VARIETIES FOR DIFFERENT AGRONOMIC AND QUALITY TRAITS

By

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ABSTRACT

An experiment was conducted at the PAU Sugarcane Research Station, Jullundur to assess the comparative performance of Co. J. 64 an early maturing high sugar variety and Co. 1148 a late maturing variety. The results showed that in the plant crop Co. 1148 gave 10.9% higher cane yield than Co. J. 64. In the ratoon crop, however, the yield differences between the two varieties were non-significant. In the matter of commercial cane sugar, Co. J. 64 continued to lead Co. 1148 variety from Mid-November to Mid-February and gave 14.9% more commercial cane sugar during this period. Co. J. 64 also gave higher commercial cane sugar than Co. 1148 for the whole season. The results indicate the desirability of cultivation of Co. J. 64 variety on commercial scale in place of Co. 1148.

Introduction

In sugarcane breeding, combining high sugar and cane yield in a genotype in general is difficult to achieve. It is easy to develop a high yielding cultivar with low sugar content and high sugar variety with low yield potential. In the varietal improvement projects at the Sugarcane Research Station, Jullundur special emphasis is being laid on the development of early maturing high sugar varieties with good yield level for the last one decade. As a result of this work Co. J. 64 - an early maturing

high sugar variety was developed and released for cultivation in Punjab in 1975. This variety combines cane yield and sugar recovery to a considerable high degree. The major area, however, under sugarcane in Punjab continues to be under, Co. 1148 - a late maturing high yielding cane variety. In order to assess the relative yield and quality performance of these two varieties, investigations were carried out at the PAU Sugarcane Research Station, Jullundur. The results of this study are reported in this paper.

Materials and Methods

A trial was laid out in a split plot design with varieties as a main plots and dates of harvesting as sub-plots. The details of treatments were as under :—

Varieties	Date of harvesting
	Mid November
Co. J. 64	Mid December
Co. 1148	Mid January
	Mid February
	Mid March.

There were four replications and the plot size was 75 sq. meter. Planting was done on 18.3.1975. Data on germination were recorded 45 days after planting and tillering data in the first week of July. The linear growth was recorded from 10 randomly selected plants from each plot in the first week of October. Both the varieties received 140 Kg. N/ha. All other agronomic practices were uniform. The plots were harvested on due dates and yield data recorded from each plot. Cane samples were drawn for juice analysis and analysed for sucrose and purity co-efficient. The millable stalk number, stalk length and stalk girth were recorded from 20 stalks from each plot at the time of harvest. The cane yield and other data were also recorded from the ratoon crop. The commercial cane sugar was worked out with the following formula :

$$[\text{Suc} - (\text{T. S.} - \text{Suc}) 0.4] \times 0.73 \times \text{cane yield.}$$

Results and Discussion

The results are presented in tables 1 and 2. The germinated shoot population was signifi-

cantly higher in Co. J. 64 variety but tiller population differences between the two varieties were non significant. Co 1148, however, gave higher tiller population than Co. J. 64. The results show that Co. J. 64 though a better germinator than Co. 1148, the latter variety had higher tillering capacity. The tiller mortality was higher in Co. 1148. The millable stalk population was higher in Co. 1148 though the differences between the two varieties were non-significant. In the matter of cane yield Co. 1148 out yielded Co. J. 64 by a significant margin giving 10.9% higher cane yield than Co. J. 64. The yield differences among the different dates of harvesting were non-significant. The higher yield in Co. 1148 variety was due to more stalk population and stalk length as compared to Co. J. 64. In the matter of commercial cane sugar, Co. J. 64 continued to lead Co. 1148 variety upto middle of February due to higher sucrose content in this variety. It was only in March that Co. 1148 gave higher commercial cane sugar than Co. J. 64. The sucrose content was also higher in Co. J. 64 right from November to February.

In the ratoon crop, yield differences between the two varieties were non-significant. Both the varieties when harvested in November and December gave significantly lower yield than the crop harvested in January, February and March. The poor yield from November-December harvested crop was due to poor sprouting resulting low plant population and ultimately the yield. In the matter of commercial cane sugar Co. J. 64 ratoon crop gave 52.2% higher commercial cane sugar than Co. 1148. These results show that Co. J. 64 gave better performance than Co. 1148

in the matter of commercial cane sugar both in plant and ratoon crop. The juice quality of Co. J. 64 was also significantly better than Co. 1148.

that the cultivation of Co. J. 64 should be encouraged in place of Co. 1148 as the former variety gives higher commercial can sugar per unit area than the latter, both in plant and ratoon crop.

From the above results, it can be concluded

Table—1 (a)

**Showing comparative performance of Co. J. 64 and Co. 1148 varieties
(Plant crop 1975-76)**

Variety	Germinated shoot population '000'/ha	Tiller population '000'/ha	Per cent tiller mortality
Co. J. 64	103.9	310.8	63.1
Co. 1148	91.4	351.1	68.7
C. D. at 5%	6.69	N. S.	N. S.

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Table - I (b)

Showing comparative performance of Co J. 64 and Co 1148 varieties (Plant crop 1975-76)

Dates	Stalk population '000/ha		Stalk length (cms)		Stalk girth (cms)		Cane yield tonnes/ha		Commercial cane sugar tonnes/ha		Juice quality	
	Co. J. 64	Co. 1148	Co. J. 64	Co. 1148	Co. J. 64	Co. 1148	Co. J. 64	Co. 1148	Co. J. 64	Co. 1148	Sucrose%	Purity
Mid November	117.6	123.9	180.0	182.5	2.29	2.16	60.0	66.0	6.86	5.47	16.3	12.7
											87.1	87.9
Mid December	109.0	115.0	178.1	120.6	2.21	2.09	58.2	61.6	6.65	5.61	17.2	13.6
											81.6	75.2
Mid January	120.2	110.8	183.5	200.6	2.33	2.18	59.2	61.5	7.27	6.23	17.9	14.9
											86.7	79.9
Mid February	98.3	113.0	172.1	175.0	2.23	2.33	57.0	60.0	7.05	6.92	18.1	16.6
											86.2	81.2
Mid March	97.5	81.3	187.8	194.5	2.06	2.00	54.8	58.7	6.75	7.72	18.0	18.0
											85.7	86.3
Mean	108.5	108.9	180.3	186.5	2.31	2.15	57.8	64.1	6.92	6.39	17.5	15.2
											85.5	80.1
C. D. at 5%												
Varities	N. S.	N. S.		0.73		1.49						
Dates	16.91	9.12		0.13		N. S.						
Interaction	N. S.	N. S.		N. S.		N. S.						

Table-2

Showing comparative performance of raton crop of Co. J. 64 and Co. 1148 (1976-77)

Dates	Cane yield tonnes/ha		Commercial cane sugar tonnes/ha		Juice quality			
	Co. J. 64	Co. 1148	Co. J. 64	Co. 1148	Sucrose	Purity		
Mid November	15.7	16.1	1.69	1.04	16.05	10.98	81.6	66.5
Mid December	24.6	23.1	2.64	1.69	16.18	11.65	81.3	67.8
Mid January	48.0	45.9	5.55	3.16	17.33	11.65	83.2	68.0
Mid February	43.3	62.9	4.93	4.04	17.00	11.05	83.2	66.0
Mid March	45.2	47.4	5.42	3.36	17.67	11.44	84.7	67.0
Mean	35.4	37.1	4.05	2.66	16.85	11.35	82.8	67.1
C. D. at 5%								
Varieties	N. S.		N. S.					N. S.
Dates	4.97		0.52			2.07		N. S.
Interaction	12.16		0.72			0.59		N. S.
						N. S.		N. S.

THE CONCEPT OF RATE OF CHANGE OF TISSUE MOISTURE AND NITROGEN AND THEIR EFFECT ON SUGAR YIELD OF SUGARCANE

By

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ABSTRACT

The experiments conducted in the farmers' fields over a period of two seasons 1974-75 and 1975-76 reveal that the rate of change of moisture and nitrogen in tissues influences the CCS%, yield and CCS. Any increase in the levels of these two nutrients in grand growth period depresses CCS%, yield and CCS. The rate of reduction of these two nutrients from 4th month to harvest linearly increases these parameters. The sugar yield is reduced if the rate of reduction of moisture and nitrogen are low, inspite of higher levels of these two nutrients at early growth phase (4th month). The sugar yield (CCS) is observed as high as 22 tonnes/ha in fields, where the moisture and nitrogen were at high levels (25.0% and 2.0%) followed by higher rates of reduction (15% and 40%). It is evident from this investigation that, by withholding irrigation 3 to 4 weeks prior to harvest will not yield more sugar. The hydration or dehydration should be attempted on physiological aspects and not by physical drying.

Introduction

The sugar yield of a homogenous field is decided by the internal composition of the plant in different growth phases, in reaction to environment. The basic relationship of these nutrients particularly moisture and

nitrogen to cane yield and quality is well established i.e., a vigorously growing variety records high levels of moisture and nitrogen during growing periods; sugar rich variety records low moisture and nitrogen at ripening phase as compared to medium or poor variety (Parthasarathy and Perumal, 1978). It has

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been also found that higher moisture and nitrogen in tissues during the early growth phases will linearly increase the yield at harvest, and lower levels of these two nutrients at the time of harvest will linearly increase the sugar content (Lakshmikantham, *et al.*, 1970; Narasimha Rao, *et al.*, 1967; Srinivasan and Mariakulandai, 1969 and 1972; Srinivasan *et al.*, 1973; Parthasarathy and Perumal, 1974, 1975 and 1976; Renganathn, 1963).

There are very few studies to bring out the behaviour of moisture and nitrogen under varying conditions of soil, climate and cultural practices including irrigation. It is commonly recommended by the sugar industries to withhold the irrigation two to three weeks earlier to harvest as one of the most important steps to bring down these two nutrients to minimum levels. There are practically no systematic studies to find out the quantum of change of these two nutrients in different growth phases and their influence on final yield and quality of cane, on commercial scale. Keeping this in view, this experiment was conducted in the cultivators' fields with the object of finding out the rate of change of moisture and nitrogen in different growth phases and their influence on sugar yield.

Materials and Methods

This experiment was conducted in about 300 farmers' fields over a period of two seasons 1974-75 and 1975-76, with three commercially cultivated varieties (ratoons) viz, (1) Co. 658, a sugar rich early variety; (2) Co. 6304, a medium, mid variety; and (3) Co. 419, poor to medium, late variety under varying soil types and cultural practices. The crops in the

farmers' fields were logged for the nutrient levels different growth phases and yield at CCS% at harvest. Only homogenous fields were selected for this study. The individual field area varied from $\frac{1}{4}$ to 5 hectares with different soil types i.e. sandy loam, clay loam and clayey. The fertilizer application was uniform to all fields i.e. 225 kgs of N, 112 kgs of P_2O_5 and 112.5 kg of K_2O . Periodic leaf sample collections were carried out as prescribed by Clements of Hawaii during the early morning hours (5.30 AM to 9.30 AM) at four different stages of growth, early growth phase (4th month), early grand growth phase (6th month), late grand phase (8th month) and at harvest. The analysis was carried out for sheath moisture percentage, and leaf nitrogen percentage by macrokjeldhal method in R & D laboratory of Kothari. The commercial cane sugar per cent (CCS%) was worked out by applying the formula given below :

$$CCS\% = 1.05 B - .307 P$$

$$B = \text{Brix } \%$$

$$P = \text{Pol } \%$$

The harvesting of these three varieties were carried out during the months of February and March. The crops which were ratooned during February and March were harvested by next February and March (12th month) and crops which were ratooned during the month of April were also harvested by February (10 months) in Co. 658, since our earlier studies showed that ratooning/planting by April and February will reach maximum sugar content (CCS%) by next February irrespective of age (months). Co. 6304 and

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Co. 419			
Sheath moisture R.M.		Leaf N% L. N.	
+ 0.29	$\pm$ 0.05	1.81	$\pm$ 0.33
1.88	$\pm$ 0.34	9.53	$\pm$ 1.74
2.15	$\pm$ 0.39	7.54	$\pm$ 1.38
5.18	$\pm$ 0.94	16.65	$\pm$ 3.04
6.98	$\pm$ 1.27	24.37	$\pm$.445

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CCS t/ha		
Co 658	Co 6804	Co 419
.3207	.0164	.0193
.3452	.4856	.3203
.0851	.0659	.3373
.4311	.3180	.5629
.6270	.6262	.7526
.3652	.3025	.3548
.5212	.7066	.6570
.2922	.5727	.4741
.4195	.4358	.6005
.6385	.7987	.8126

Co. 419 were harvested only after 12 months age. So, the average age for Co. 658 is about 11 months and for the other two, it is 12 months.

(RM) and per cent nitrogen (RN) is worked out as shown below. There was great variation in moisture and N% from 4th month to harvest i.e., 76%–86% at 4th month and 72%–79% at harvest). 1.5 to 2.30% at 4th month and 1.0 to 1.6% of N at harvest.

The rate of change in per cent moisture

1. $RM\ 4-6 = \frac{\text{Moisture \% at 4th month} - \text{moisture \% at 6th month}}{\text{Moisture \% at 4th month}} \times 100$
2. $RM\ 6-8 = \frac{\text{Moisture \% at 6th month} - \text{moisture \% at 8th month}}{\text{Moisture \% at 6th month}} \times 100$
3. $RM\ 4-8 = \frac{\text{Moisture \% at 4th month} - \text{moisture \% at 8th month}}{\text{Moisture \% at 4th month}} \times 100$
4. $RM\ 8-H = \frac{\text{Moisture \% at 8th month} - \text{moisture \% at harvest}}{\text{Moisture \% at 8th month}} \times 100$
5. $RM\ 4-H = \frac{\text{Moisture \% at 4th month} - \text{moisture \% at harvest}}{\text{Moisture \% at harvest}} \times 100$

The rate of change of per cent of nitrogen was also worked out as in sheath moisture and designated as R.N 4-6, R.N 6-8, R.N 4-8, R.N, 8-H, R.N 4-H.

Correlation coefficients were worked out for these two parameters in different growth phases with CCS% yield and CCS and simple linear regression were worked out wherever it is necessary.

Results and Discussions

There is an increase in sheath moisture level from 4th month to 6th month in all the three varieties (table 1). The rate of reduction of sheath moisture from 4th month to harvest is highest in Co 658 (9.09%) followed by Co 6304 (0.60%) and Co 419 shows the least rate of reduction (6.9%). The high rate of reduction of moisture from 4th month to

harvest in Co 658 is partly due to the reduction from 4th month to 8th month and partly due to the reduction during the ripening phase (5.74%). The same trend is observed in Co 6304 with slightly lower values i.e., 3.03% during grand growth period and 5.95% during the ripening phase. It is interesting to note that the rate of reduction in Co 419 is mainly during the ripening phase i.e., from 8th month to harvest (5.18%) and the reduction during grand growth period is very little when compared to the other two varieties.

There is a decreasing trend in nitrogen levels from 4th month onwards. The rate of reduction of nitrogen shows the same trend as sheath moisture. The highest reduction from 4th month to harvest was observed in Co 658 (29.98%) followed by the other two varieties. (23.96% and 24.39%). The rate of reduction

in Co 6304 and Co 658 is due to the reduction in grand growth phase and ripening phase, whereas in Co 419, 68% of the reduction is in ripening phase (16.65 out of 24.39). The behaviour of sheath moisture and nitrogen in the plant system is directly related with each other, in other words, they were interdependent to each other as reported earlier, (Parthasarathy and Perumal, 1975, 1978).

The rate of reduction of those two nutrients per month in all the growth phase (fig 1 and 2) shows that there is variation in the rate of reduction of these two nutrients in grand growth phase i.e., 1.9% and 6.8% in Co 658; 1.6% and 5.2% in Co 6304 and 1.1% and 3.7 in Co 419. Much variation is not observed in these two parameters during ripening phase. This suggests that the variations in CCS% yield and CCS are mainly due to the rate of reduction of moisture and nitrogen in tissues during the growth phase 6th to 8th month).

The highest 'r' values of the rate of reduction in moisture and nitrogen from 4th month to harvest in all the three varieties with CCS% yield and CCS% suggest the necessity of maintaining high levels of moisture and nitrogen at early growth phase 85.86% of moisture and 2-2.20% N and bring down to minimum levels of 73% and 1.2% of moisture and nitrogen respectively, so that the rate of reduction will be 15% in moisture and 40% in nitrogen (table 2). Unless the rate of reduction is high, maintaining high moisture and nitrogen at early growth phase will not yield the expected CCS% yield and CCS as shown in table 3, and also observed by earlier

workers (Srinivasan and Mariakulandai, 1969; Parthasarathy and Perumal, 1977). Since earlier findings reveal that if lower level of moisture % and nitrogen at harvest goes below 73%, 1.0% respectively, the recoverable sugar was reduced because of the low extraction percentage and high fibre %, bringing down these nutrients below this level, is not advisable (Parthasarathy and Perumal, 1977). In earlier investigation, the relation of moisture and nitrogen at 4th month with CCS% showed positive relation, but the 'r' values were comparatively lower than the yield. In all three varieties the rate of reduction of moisture and nitrogen from 4th month to harvest is positively correlated with CCS% to the highest level of significance, when compared to yield, and this relation explains that the rate of reduction which was not accounted in earlier studies by others, while relating these two nutrients at 4th month final CCS%, might be the cause in weakening the relation of moisture and N with CCS%. The findings of the present investigation stress the importance of maintaining high nutrient levels at 4th month coupled the higher rates of reduction to achieve higher sugar yield.

The significant correlation coefficients of rate of change of moisture and nitrogen from 8th month to harvest with CCS% yield and CCS in all the three varieties leaves lot of scope for improving the sugar yield by bringing down these nutrients without affecting the yield. Any attempt to bring down these nutrients at the time of harvest must be gradual and physiological i.e., from 8th month to harvest in (Co 419 and Co 6304) mid and late varieties and from 6th month to harvest in the case of early varieties (Co 658).

The present practice of withholding the irrigation 3 or 4 weeks prior to harvest results in physical dehydration and thereby reducing the recoverable sugar because of high fibre content and low extraction %.

The prediction equations are fitted for

data collected from varying conditions of soils, seasons, cultural practices including irrigation as presented in Table 3. It is evident that the potentiality of improving the sugar yield is not reached under the present set of conditions.

Table—3

Linear regressions of rate of reduction of X_1 moisture and X_2 nitrogen from 4th month to harvest with Y_1 CCS% Y_2 yield Y_3 CCS/hectare

Sheath moisture X_1	Leaf nitrogen X_2
Co 658	
$Y_1 = 10.11 + .17 X_1$	$Y_1 = 10.62 + .05 X_2$
$Y_2 = 73.69 + 3.45 X_1$	$Y_2 = 79.94 + .87 X_2$
$X_3 = 7.40 + .57 X_1$	$Y_3 = 8.01 + .15 X_2$
Co 6304	
$Y_1 = 9.38 + .22 X_1$	$Y_1 = 9.78 + .06 X_2$
$Y_2 = 98.81 + 1.78$	$Y_2 = 93.06 + .88 X_2$
$Y_3 = 9.12 + .45 X_1$	$Y_3 = 8.90 + .17 X_2$
Co 419	
$Y_1 = 9.33 + .26 X_1$	$Y_1 = 9.79 + .05 X_2$
$Y_2 = 94.30 + 5.06 X_1$	$Y_2 = 105.48 + .99 X_2$
$Y_3 = 8.60 + .86 Y_1$	$Y_3 = 10.26 + .18 X_2$

Table 4

Percent change of sheath moisture, CCS% Yield and CCS

Initial moisture %at 4th month	Moisture% at harvest	RM 4-6	RM 4-8	RM 4-H	CCS%	Yield tonnes per ha.	CCS tonnes per ha.
Co658							
80.2	79.3	+2.24	+4.86	1.12	10.02	87.258	8.743
80.9	77.0	+1.73	2.35	4.82	11.53	60.625	6.990
82.0	72.4	+3.90	7.32	11.71	13.44	118.75	15.960
83.6	73.0	+0.57	4.07	12.68	13.02	141.050	18.355
83.8	76.1	2.15	6.44	9.19	12.70	134.550	17.088
86.7	73.9	2.54	7.38	14.76	13.42	165.325	22.187
Co 6304							
80.0	77.6	+3.62	+4.25	3.00	9.67	73.300	7.088
82.4	79.8	+2.06	+2.06	3.16	11.17	118.800	13.271
81.9	74.7	+1.86	2.32	8.79	11.34	82.588	9.365
84.1	78.2	+2.50	1.07	7.02	9.79	121.505	11.895
84.3	75.0	+1.66	2.73	11.03	12.82	144.295	18.499
84.7	73.6	+1.06	3.66	13.11	12.93	155.688	19.633

(Contd.)

Initial moisture % at 4th month	Moisture % at harvest	RM 4-6	RM 4-8	RM 4-H	CCS%	Yield tonnes per ha.	CCS tonnes per ha.
Co 419							
81.0	79.7	0.37	0.99	1.98	9.90	90.000	8.910
84.6	79.9	+2.60	5.32	5.36	10.68	130.370	13.924
85.5	80.4	1.75	1.05	5.96	9.23	127.038	11.720
84.2	76.8	+1.07	1.66	8.79	12.70	130.250	16.542
86.6	76.5	+0.81	1.27	11.66	12.29	147.237	18.095
86.0	77.3	0	3.49	10.12	12.74	154.950	19.626

Note : + indicates that there is an increase. In all other values there is decrease.

In this investigation, it is found that crops with high moisture levels (Table 4) at early growth phase followed by higher reduction rates (86.7 to 73.9 and 14.76) recorded higher CCS% (13.42%), (165 325 t/ha) and CCS, (22.187 tons/ha) in Co 658 variety. Fields with Co 419 recorded with high moisture level and higher rate of reduction from 4th month to harvest (86.0 to 77.3 and 10.12%) yielded high CCS% (12.74%), yield (154.050 t/ha) and CCS (19.626 t/ha) whereas there was low CCS% (9.23%) yield (127.038 t/ha) and CCS (11.720 t/ha) when the rate of reduction was low (5.96) from 4th month to harvest in spite of the high moisture level (85%) at early growth phase. The same trend is observed in nitrogen also. Normally under farmers' field conditions, the Co 658 showed low levels of moisture and N at early growth phase (fig. 3) and high rate of reduction

(14%) with 10-12 months age, whereas Co 419 showed higher moisture and nitrogen, at early growth phase but lower reduction rate (8-10%) in 12 months age. Co 6304 was in between these two varieties. The higher levels of moisture and nitrogen at early growth phase and their reduction in Co 658, and higher reduction rate in Co 6304 and Co 419 observed in good farmers' fields, leaves lot of scope for agronomists and physiologists to design the experiments to exploit the varietal potential for more sugar yield. The CCS% and yield are the resultants of the interaction between environment and the genetic make up of the varieties. Unless the varieties are provided with the favourable environment to maintain high moisture levels at early growth phase followed by higher rate of reduction, from 4th month to harvest, otherwise the genotypical

expressions for higher CCS% and yield are masked. The findings of the present investigation shows that, at the present climatic conditions, the CCS will go as high 20 tonnes/ha as against the present low levels of CCS (9 tonnes/ha) leaving great scope for improvement. This improvement could be done through diagnosis of the crop in the farmers' fields by establishing growth analysis field laboratories in sugar factory zones.

Acknowledgement

The author is grateful to the management

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RATE OF CHANGE OF PERCENT SHEATH MOISTURE PER MONTH AT DIFFERENT GROWTH PHASES

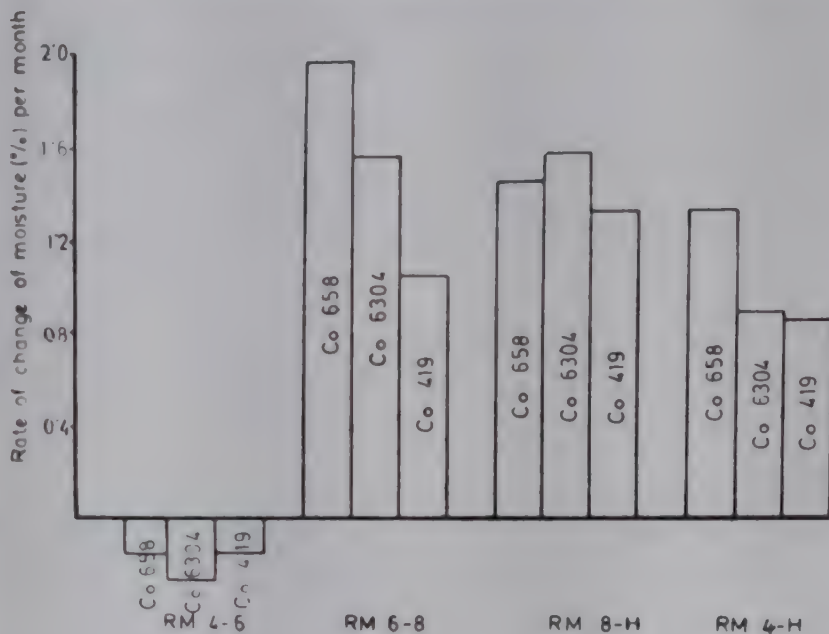


Fig. 1

RATE OF CHANGE OF LEAF N (%) PER MONTH AT DIFFERENT GROWTH PHASES

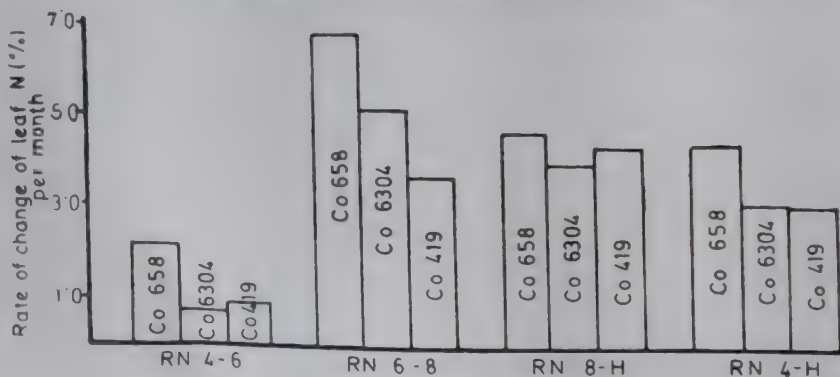


Fig. 2

SHEATH MOISTURE % & NITROGEN IN DIFFERENT GROWTH

PHASES

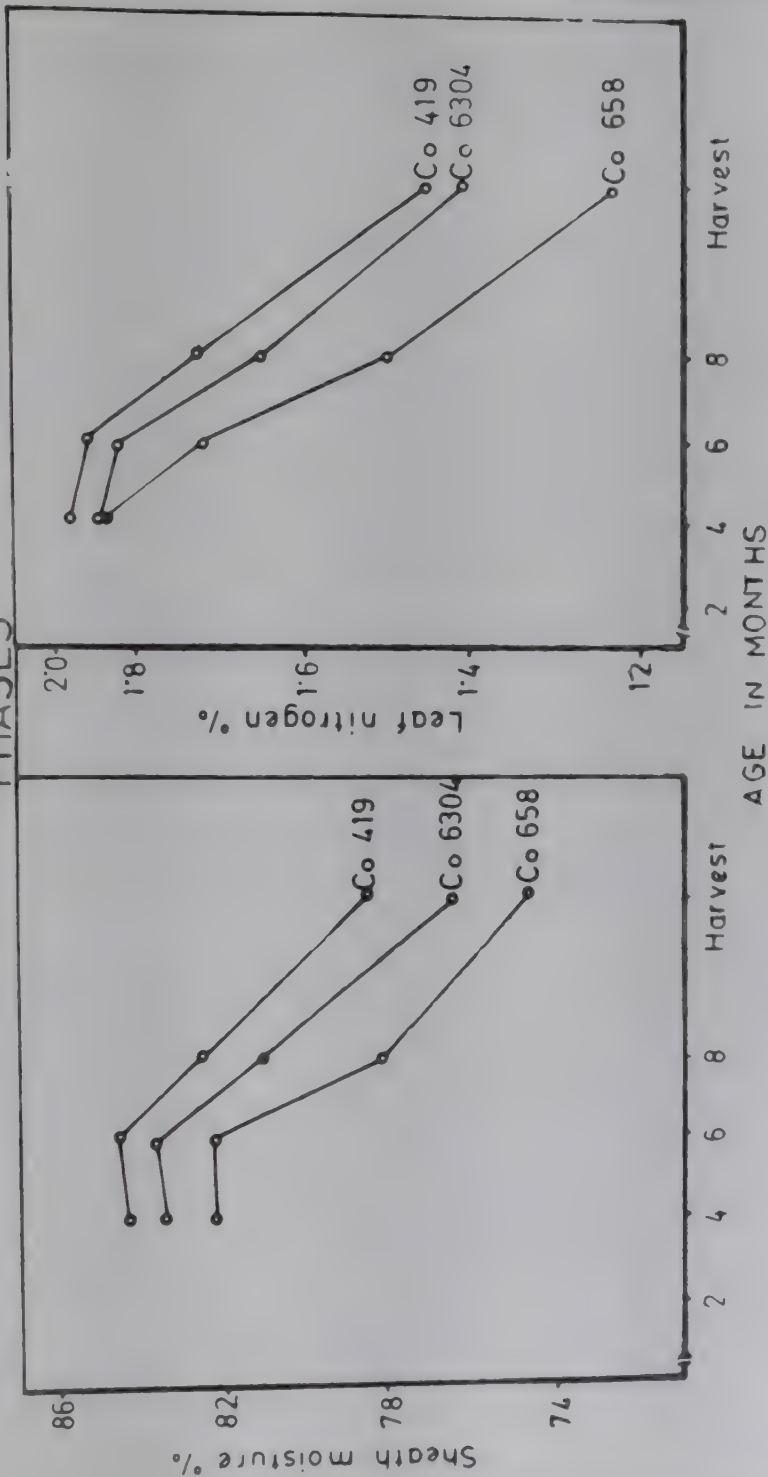


Fig. 3

LINEAR REGRESSION OF RATE OF REDUCTION
OF SHEATH MOISTURE AND CCst/ha

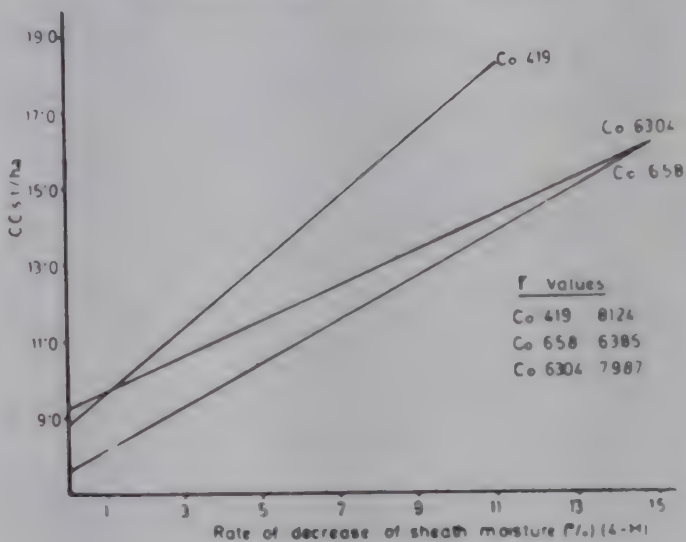


Fig. 4a

LINEAR REGRESSION OF RATE OF
DECREASE OF N (%) (4-H) & CCst/ha

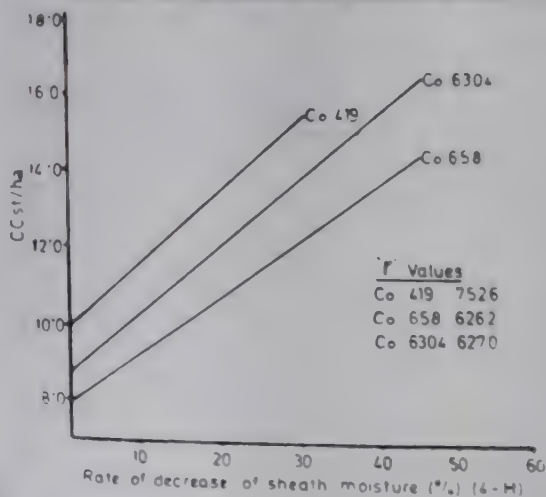


Fig. 4b

LEGUMINOUS INTERCROPS FOR SUGARCANE

By

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ABSTRACT

A field experiment conducted at Regional Research Station, Mandya (Karnataka) during 1975-76 and 1976-77 revealed the possibility of intercropping late planted (Jan-March) sugarcane with leguminous crops like greengram, groundnut, field bean and cowpea. The percent increase in income over no intercrop was highest in groundnut (44.34) and cowpea (32.83) intercropped with sugarcane during 1975-76 and 1976-77 respectively.

Introduction

Sugarcane being a long duration crop (12-18 months) and slow in germination (one to one and a half month) the full space provided between two rows (90 cm) is covered in about 3½ to 4 months time after planting. If Sugarcane is grown alone, the available soil, solar energy and the soil moisture are not fully utilised during this 3½ to 4 months period. Hence, in order to maximise the total output in the given area intercropping sugarcane without affecting the yield of main crop substantially is the problem to be worth solving. To accomplish this goal, the intercrops must keep freely their own photosynthetic area without interception (Loh, 1968). According

to Tang (1963), the success of interplanting depends upon the selection of right varieties of the two interplanted crops. The intercrop in sugarcane should preferably be a leguminous crop to have the beneficial effect of nitrogen fixation symbiotically on the main crop as well as to lessen the competition for N (Nadagoudar *et al.*, 1975). Short duration intercrops which could be harvested in early stages of the cane growth may meet the immediate needs (Lakshmikantam *et al.*, 1971, Kirtikar and Nath, 1965 and Mathur *et al.*, 1968). In South Karnataka, Sugarcane yields are low when planted during the late winter and summer (Jan.-Mar.) because of very high intensity of flowering in such crops when it is only 9-10 month old. This could be overcome

by taking an intercrop to rise the total output. In view of the above and possibilities of increasing production of raw material per unit area an experiment was conducted for two years.

Materials and Methods

A field experiment was conducted in red sandy loam soils at Regional Research Station, Mandya (Karnataka) for two years during 1975-76 and 1976-77. Intercrops included were only leguminous types to avoid competition for nitrogen if cereals are included and to take advantage of symbiotically fixed nitrogen to sugarcane crop. Two methods of planting, viz. (1) normal method of planting sugarcane in 90 cm. furrows and two rows of intercrops on either side of the ridge during 1975-76 and only one row during 1976-77 (2) two rows of sugarcane in 60 cm. wide furrow and five rows of intercrops on a wide ridge of 120 cm between two such pairs of sugarcane rows during 1975-76 and only three rows during 1976-77 in the main plot and six intercrops with control in sub-plot were tried. The experiment had four replications laidout in split plot design. The plot size was 57.6 and 72.0 m² during the two years. Sugarcane was planted on 17.1.75 during 1975-76 and 23.1.76 during 1976-77. The intercrops were planted after 2 days of planting sugarcane when the soil conditions were congenial. The intercrops were harvested at physiological maturity except field beans which were harvested for green pods for vegetable purpose. The crop, varieties and their duration as recorded in the experiment is presented in Table 1. Varieties in cowpea and field bean were changed during 1976-77 as the varieties used during 1975-76 had bushy growth affecting sugarcane, through

reduced tillering, adversely. Variety Co. 419 of sugarcane was used as the main crop during both the years. A recommended dose of 250, 100, 125 kg of N, P₂O₅ and K₂O was applied per ha. to sugarcane. Grain weight was recorded after sun drying for 4-5 days at 16.20% moisture while fodder weight was recorded immediately after harvesting at 50-58% moisture. In this paper yield of both intercrops and main crop (Sugarcane) and their economics is discussed.

Results and Discussions

Economics of taking intercrops in sugarcane mainly depends upon the market price for the produce of intercrops and sugarcane. However Sugarcane being main crop, the yield of this crop should always be the criteria on for judging. Intercrops yields (Table 2 and 3) differed significantly in both main plots and sub plots during the two years. In the normal method of planting, the yields were always less than in the paired row method of planting. The difference was to an extent of 5.12 q. per ha. grain, 15.75 q. per ha. fodder during 1975-76 and 3.38 q. per ha. grain, 11.66 q. per ha. fodder during 1976-77. The increased yield in paired row planting was due to higher population (more rows) of intercrops.

Amongst inter crops, field bean recorded the highest yield of 44.22 q. per ha. (green pods followed by groundnut (39.63 q./ha.) and cowpea (22.86 q./ha.) while the fodder yield was highest in cowpea with 116.84 q. per ha. followed by groundnut (86.05 q./ha.) and field bean (72.70 q./ha.) during 1975-76. During the year 1976-77, field bean and groundnut recorded more or less the same

yield with 10.74 and 10.67 q. per ha. respectively followed by soybean 8.99 q. per ha. and cowpea 7.49 q. per ha. The fodder yield was highest in groundnut with 76.21 q. per ha. followed by cowpea 44.95 q. per ha. and greengram 23.69 q. per ha. Low yield during 1976-77 in all the intercrops and methods of planting was due to lower population (lesser rows) than in 1975-76.

Sugarcane yields did not differ significantly in the two methods of planting during both the years. In different intercrops, the sugarcane yields varied significantly only during 1975-76. Sugarcane without intercrops recorded significantly higher cane yield (87.69 tonnes ha.) over all inter crops sugarcane. Blackgram, Groundnut, Greengram, field bean intercropped with sugarcane were next best with 71.60, 71.50, 70.61 & 65.41 tonnes per ha. respectively without any significant difference among them. Intercropping sugarcane with Soybean and cowpea separately, recorded significantly lower yield with only 53.70 and 42.24 tonnes per ha. respectively than other intercrops and no intercrops. During 1976-77, greengram and cowpea intercropped sugarcane recorded about 10 tonnes per ha. more yield than sugarcane alone with 80.12 tonnes per ha. followed by soybean and groundnut with 80.56 and 78.92 tonnes per ha. respectively. Sugarcane yields were higher during 1976-77 which was due to reduction in competition between sugarcane and intercrops owing to fewer number of rows (nearly half) of intercrops. This not only reduced the competition but also permitted to take up one inter cultivation before the harvest of intercrops which was not possible during 1975-76.

Total value of the main as well as intercrops

was highest in groundnut + sugarcane with Rs. 17,720/- per ha. followed by field bean + sugarcane with Rs. 14,234/- per ha. and greengram + sugarcane with Rs. 13,635/- per ha. during 1975-76. The increased income over on intercrop in sugarcane was to an extent of Rs. 5,443, Rs. 1,957 and Rs. 1,358/-per ha. in groundnut, field bean and greengram intercropped sugarcane respectively. Intercropping sugarcane with soybean decreased the income by Rs. 2,636 per ha. as compared to sugarcane alone. During 1976-77, when the number of rows of intercrops were reduced and two crop varieties were changed owing to their bushy type of growth affecting adversely the tillering of sugarcane thus reducing the sugarcane yields cowpea + sugarcane recorded the highest value of Rs. 14,899 per ha. followed by greengram + sugarcane Rs. 14,008 per ha. Intercropping sugarcane with groundnut or soybean recorded almost the same value with only Rs. 49 per ha. higher value in soybean. The increased income over no intercrop was to an extent of Rs. 3,683, Rs. 2,791, Rs. 2,434 and Rs. 2,385 per ha. in cowpea, green gram, soybean and groundnut intercropped sugarcane respectively. Intercropping sugarcane with blackgram reduced the income by Rs. 417 per ha. as compared to sugarcane alone.

On working out the percent increase in income over no intercrop groundnut, field bean and greengram were found superior during 1975-76 and cowpea, greengram, groundnut, or soybean during 1976-77. Hence, intercropping sugarcane with greengram or groundnut or field bean or cowpea may work well in increasing the total output and profits depending upon the market prices.

Table --1

Crop, varieties and their duration of Inter crops as recorded in the Experiment

Sl. No.	Crops	Varieties	Duration in days.
1.	Green gram (<i>Phaseolus radiatus</i> L.)	Hybrid 45	96
2.	Blackgram (<i>P. mungo</i> L.)	T-9	95
3.	Cowpea (<i>Vigna catjang</i> Walp)	C - 152 (1975-76)	96
		Verginia (1976-77)	95
4.	Field bean (<i>Dolichos lab lab</i> Hebbal)	Avare Type 1 (1975-76)	98
		„ „ 3 (1976-77)	90
5.	Groundnut (<i>Arachis hypogaea</i> Willd)	Spanish improved	120
6.	Soybean (<i>Glycine max</i> L.)	Hardee	122

Table—2

Yield of inter-crops (Grain and Fodder) and Sugarcane, their income in different combinations during 1975-76

Treatments	Intercrops Yield Q./ha.		Value of grain & Fodder Rs./ha.	Cane Yield Tonnes/ha.	Value of cane Rs./ha.	Total value of intercrop and main crop Rs/ha.	Increased income over no intercrop	% Increase over no inter crop
	Grain	Fodder						
1. Normal	20.37	60.64	4,177.50	72.29	10,120.60	14,298.10	—	—
2. Paired	25.49	76.39	5,280.77	59.92	8,388.80	13,669.57	—	—
CD at 5%	0.94	2.11	—	N. S.	—	—	—	—
CD at 1%	2.99	3.87	—	N. S.	—	—	—	—
1. Control	—	—	—	87.69	12,276.60	12,276.60	—	—
2. Green-gram	10.71	59.63	3,749.67	70.61	9,885.40	13,635.07	1,358.47	11.07
3. Blackgram	12.98	38.96	2,946.64	71.60	10,024.00	12,970.64	694.04	5.65
4. Cowpea	22.86	116.84	6,766.51	42.24	5,913.60	12,680.11	403.51	3.29
5. Fieldbean	44.22	72.70	5,076.30	65.41	9,157.40	14,233.70	1,957.10	15.94
6. Groundnut	39.63	86.05	7,709.70	71.50	10,010.00	17,719.70	5,443.10	44.34
7. Soybean	7.16	36.92	2,122.28	53.70	7,518.00	9,640.28	2,636.32	26.47
CD at 5%	5.75	3.05	—	15.43	—	—	—	—
CD at 1%	7.74	4.11	—	20.91	—	—	—	—

Note :— Value of produce has been worked out at Rs. 250/q. for Cowpea, Rs. 300/q. for greengram, Rs. 200/q. for Blackgram Rs. 175/q. for Groundnut, Rs. 250/q. for Soybean Rs. 100/q. for Fieldbean green pods, Rs. 140/tonnes for cane and for Green Fodder Rs. 9/q., as prevailed in the local market.

Treatment	Intercrop Yield Q/ha.		Value of grain and fodder Rs./ha.	Cane Yield Tonnes/ha.	Value of cane Rs./ha.	Total value of intercrop and main crop Rs./ha.	Increased income over no inter crop	% increase over no inter crop
	Grain	Fodder						
1. Normal	5.47	25.03	1,298.10	86.78	12,149.20	13,447.30	—	—
2. Paired	8.85	36.69	2,081.75	76.20	10,668.00	12,749.75	—	—
CD at 5%	1.49	7.53	—	N. S.	—	—	—	—
CD at 1%	2.17	N. S.	—	N. S.	—	—	—	—
1. Control	—	—	—	80.12	11,216.80	11,216.80	—	—
2. Greengram	3.53	23.69	1,272.21	90.97	12,735.80	14,008.01	2,791.21	24.88
3. Blackgram	1.56	9.37	296.33	74.31	10,403.40	10,799.73	417.07	3.72
4. Cowpea	7.49	44.95	2,277.05	90.16	12,622.40	14,899.45	3,682.65	32.83
5. Fieldbean	10.74	17.01	1,227.09	75.31	10,543.40	11,770.49	553.69	4.94
6. Groundnut	10.67	76.21	2,553.14	78.92	11,048.80	13,601.94	2,385.14	21.26
7. Soybean	8.99	13.89	2,372.51	80.56	11,278.40	13,650.91	2,434.11	21.70
CD at 5%	2.03	5.60	—	N. S.	—	—	—	—
CD at 1%	2.73	7.54	—	N. S.	—	—	—	—

Note :— Value of produce has been worked out at the same prices as in 1975-76 which also prevailed during 1976-77 in the local market

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STUDIES ON THE POSSIBILITY OF RAISING SHORT DURATION CROPS OF SUGARCANE

By

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ABSTRACT

The performance of Co A 7601 and Co 997 crops planted in alternate months commencing from last week of January to end of November 1977 and harvested at 6 or 8 months age was studied at Sugarcane Research Station, Anakapalle. The data so far are available from crops planted up to end of July. The result indicated that it is possible to grow short term crops of 8 months duration with remunerative sugar content by resorting to planting in June-July using 6 weeks old Rayungans as seed material. Performance of Co A 7601 was distinctly better than that of Co 997 in this respect. But Co A 7601 is highly susceptible to rust under natural conditions. A variety with similar yield and juice quality as Co A 7601 but devoid of rust incidence under natural conditions has to be selected if short term crops are to be grown.

Introduction

Most of the sugarcane crops in India are about 12 months or less in duration whether they are plant or ratoon crops. About 5% of the total area in the country is put to 16 to 20 months duration crops termed 'adsali' crops. These are raised in parts of Maharashtra and Andhra Pradesh. Some small area in the northern States is raised to autumn planted

crops of about 15 to 16 months duration. If sugar production per unit area and time is to be increased, duration of sugarcane has to be reduced.

The life cycle of sugarcane may be divided into three phases viz. formative (first 120 days); grand period of growth (150 to 170 days) and maturity period (300 to 360 days). If a short term crop is to be grown, these three phases

have to be telescoped into each other with minimum adverse effect on cane yield and juice quality. Hence, to find out the best period for planting short term cane crops, studies were initiated at Sugarcane Research Station, Anakapalle during 1977-78 utilising Co. A 7601 and Co. 997. Plantings were done in alternate months commencing from January 1977 and harvestings of each planting were done at 6 or 8 months. Incidentally the relative merits of rayungans and single budded settlings as seed material for growing these crops were also studied. The results though of a preliminary nature and quantitatively very limited have been presented in this paper because of wide spread interest in the problem and indication of a specific trend.

Review of Literature

In studies conducted at several research stations including Sugarcane Research Station, Anakapalle, optimum time of planting was sought to be determined. It was seldom, if at all, coupled with age at harvest (Anonymous 1958).

As is well known, it is not the mere age of the crop that determines the yield and quality of sugarcane. The climatic conditions and seasonal sequence that occurred during the life cycle of sugarcane as also the duration for which a particular type of seasonal conditions prevailed with reference to the stage of development of the crop have a determining influence on the yield and quality of the same (Varahalu 1936).

In order to take full advantage of the favourable growing conditions that prevail, the plant should reach a minimum stage of develop-

ment (Ayres 1936).

The crop had to put on a certain minimum amount of vegetative growth to take full advantage of favourable growing conditions of a season (June-July to October) and accumulate enough sugar to be economic for harvest at 12 months or less age. This minimum could be attained only when the crop was planted from January to June (Lakshmikantham 1965).

When plantings were delayed till the first week of May (instead of being completed in February-March) and the crop harvested in the immediately following crushing season i. e. January-April, using rayungans single budded setts in the interests of better juice quality (Lakshmikantham and Prasadarao 1960).

However, planting rayungans of Co 419 and Co 527 as late as August did not enable realisation of crops with juice quality of economic value in the harvest season immediately following planting (March-April). But 'rayungans' planted crops had better vegetative development and juice quality than the sett planted crops. (Lakshmikantham and Prasadarao 1958).

Material and Methods

Two varieties, Co 997 and Co A 7601 were planted on a 'garden land' in shallow furrows spaced 80 cm. apart in alternate months commencing from January using six weeks old rayungans or single budded settlings as seed material. The seed rate adopted was 30000 rayungans or settlings per hectare. Rayungans or settlings received three irrigation after planting on alternate days to

Table—1

PARTICULARS OF JUICE QU

Month of planting	Month of harvest and juice characters	Harvest at 6 months age			
		Co A 7601		Co 997	
		Rayungans	Settlings	Rayungans	Settlings
January '77	July '77				
	Sucrose %	8.14	8.20	7.82	8.19
	Purity %	67.50	70.93	63.96	64.61
March '77	September '77				
	Sucrose %	11.89	12.28	9.34	8.65
	Purity %	78.62	76.36	67.36	62.79
May '77	November '77				
	Sucrose %	12.64	10.61	12.24	11.43
	Purity %	76.69	72.37	76.69	75.39
July '77	January '77				
	Sucrose %	17.70	16.04	14.52	14.64
	Purity %	93.16	89.11	82.50	83.18
September '77	March '77				
	Sucrose %	12.16	10.90	10.34	10.25
	Purity %	80.10	76.58	72.71	74.93

Particulars of juice quality of crops raised with setts in February and harvested at 10 month in Dec

Variety	% Juice sucrose
Co A 7601	18.40
Co 997	17.54

Ag 36 A

months age

Co 997

Rayungans Settlings

12.33 12.50

78.48 77.11

15.14 14.50

84.77 83.23

18.43 16.77

90.34 88.03

17.48 17.53

90.16 90.45

9.96 9.39

71.55 73.82

Harvest at 8 months age

Co A 7601

Co 997

Rayungans

Settlings

Rayungans

Settlings

77.50

60.62

79.23

65.52

81.35

68.99

70.31

60.52

67.50

62.50

68.12

61.87

70.83

62.50

68.33

65.21

79.37

72.50

75.42

70.00

control measures for the pest cannot be executed without their help or rather these are the persons who are responsible for taking action to control the pest. Most of the speakers in the seminar expressed the concern about the gravity of the situation due to the scale insects infestation in the area stressed upon immediate action to be taken to control the pest. Some of the representatives from the sugar factories complained regarding supply of cane seed material infested with scale insects from the Research Station, Gorakhpur due to which the pest has been spreading in unaffected areas. The seminar was held in the month of June, 1977 but not control measure were taken by any agency and the pest spread up in more areas. A survey were conducted jointly by the Research, staff, local cane officials from the society and the factory authorities in the month of October, 1977 at the instance of the Minister for Cane. Development of U. P. Government and about 45 to 55% cane fields of the ratoon cane crop were found affected by the scale insects in the cane areas of Padrauna, Captainganj and Lakshmiganj sugar factories. This clearly indicated the lack of interest and unresponsiveness of the concerned department officials towards the control measures for the pest to safe guard the cane grower and the sugar factories from the huge loss.

6. Suggested Control Measures for Scale Insects and Their Limitations :

Scale insects are mainly spread through the transport of seed material from the infested areas to the new planting areas. They also disseminate by sticking to the bodies of human being and animals. Strong winds too carry

them from one cane field to another. The control measures for the pest being suggested to the cane growers by the departmental officials as well as the sugar factories staff are :

- a) Selection of healthy cane seed material for new planting.
- b) Avoid growing cane varieties susceptible to the pest and have enveloping leaf sheaths.
- c) Dipping the cane setts before sowing in 'Aldrine or Malathion'.
- d) Dig out the stubble after harvest and burn them along with cane trash.

It is suggested that instead of giving the control measures to the poor-cane growers who have very limited resources, the control should be carried out by the department and the sugar factories themselves. There is a big Sugarcane Seed Corporation in the State where the prime duty is to distribute healthy cane seed material among the cane growers. The corporation should look after the a, b and c-suggested control measures. Further, the system of cane supply in the State is such, that the entire cane crop of the pest affected cane field is not harvested at a time but the same is carried over for months together. In these circumstances, how it is possible to burn the part of the field after digging out the stubbles. The pest is migrated from the partly harvested cane field easily. As such, it is suggested that the Departmental officials like the District Cane Officer, or Senior Cane Development Inspector or the Cane Protection

have to be telescoped into each other with minimum adverse effect on cane yield and juice quality. Hence, to find out the best period for planting short term cane crops, studies were initiated at Sugarcane Research Station, Anakapalle during 1977-78 utilising Co. A 7601 and Co. 997. Plantings were done in alternate months commencing from January 1977 and harvestings of each planting were done at 6 or 8 months. Incidentally the relative merits of rayungans and single budded settlings as seed material for growing these crops were also studied. The results though of a preliminary nature and quantitatively very limited have been presented in this paper because of wide spread interest in the problem and indication of a specific trend.

Review of Literature

In studies conducted at several research stations including Sugarcane Research Station, Anakapalle, optimum time of planting was sought to be determined. It was seldom, if at all, coupled with age at harvest (Anonymous 1958).

As is well known, it is not the mere age of the crop that determines the yield and quality of sugarcane. The climatic conditions and seasonal sequence that occurred during the life cycle of sugarcane as also the duration for which a particular type of seasonal conditions prevailed with reference to the stage of development of the crop have a determining influence on the yield and quality of the same (Varahalu 1936).

In order to take full advantage of the favourable growing conditions that prevail, the plant should reach a minimum stage of develop-

ment (Ayres 1936).

The crop had to put on a certain minimum amount of vegetative growth to take full advantage of favourable growing conditions of a season (June-July to October) and accumulate enough sugar to be economic for harvest at 12 months or less age. This minimum could be attained only when the crop was planted from January to June (Lakshmi-kantham 1965).

When plantings were delayed till the first week of May (instead of being completed in February-March) and the crop harvested in the immediately following crushing season i. e. January-April, using rayungans single budded setts in the interests of better juice quality (Lakshmikantham and Prasadarao 1960).

However, planting rayungans of Co 419 and Co 527 as late as August did not enable realisation of crops with juice quality of economic value in the harvest season immediately following planting (March-April). But 'rayungans' planted crops had better vegetative development and juice quality than the sett planted crops. (Lakshmikantham and Prasadarao 1958).

Material and Methods

Two varieties, Co 997 and Co A 7601 were planted on a 'garden land' in shallow furrows spaced 80 cm. apart in alternate months commencing from January using six weeks old rayungans or single budded settlings as seed material. The seed rate adopted was 30000 rayungans or settlings per hectare. Rayungans or settlings received three irrigation after planting on alternate days to

establish them. Later, the crops received irrigations once in about 10 days in the absence of rain. The crops received 112 kg. N per hectare in two doses viz. 30% at planting and the balance on 45th day after planting. Harvesting was done at 6th or 8th month ages of the crops. The lay out was single series with a gross plot size of 76.8 m² and net plot size of 48.0 m². At each harvest, besides recording per cent establishment of the pre-germinated setts, stalk population, length of milliable cane, per cent juice sucrose and reducing sugars, coefficient of purity, cane and sugar yields at harvest were recorded. In the interests of brevity, details regarding cane and sugar yields and juice quality have only been furnished, except while dealing with the relative merits of rayungans and settlings as seed material. Whether the different characteristics exhibited by the crops grown using rayungans and settlings as seed material differed significantly or not was tested taking the variants as paired and applying 't' test.

Results and Discussion

Percent Establishment

Irrespective of the variety and month of planting the variation in per cent establishment of rayungans was between 80.0 to 95.8 while in settlings it was from 77.6 to 90.8. Even in summer months such a high establishment could be obtained apparently because of appropriate scheduling of irrigations.

Juice Quality

Due to curtailment in age and scope of development of plants, cane yields of short term crops tend to be low. Hence, if short

term crops are to give high sugar yield and be remunerative, they must have appreciable high juice quality at harvest. It is desirable that the juices have a minimum of 18.0% sucrose with not less than about 85% purity. This level of juice quality was noted to have been realised in CoA 7601 crops raised in May and July only, using rayungans as seed material and harvested at 8 months. In Co 997 May planted crops only satisfied this criterion at the age of 8 months. CoA 7601 always registered better juice quality than Co 997.

When harvests were done at six months age, crops were noted to have, in general, extremely poor juice quality irrespective of variety, month of planting and type of seed material indicating that it may not be possible to reduce the duration of sugarcane crops to six months. The data are presented in table. 1.

The juice sucrose values of crops of CoA 7601 planted in May (19.52%) and July (18.18%) using six weeks old rayungans as seed material and harvested at 8 months age were noted to be comparable to that of normal crop (sett planted) harvested in December at 10 months age (18.40%). Similarly the juice sucrose value of a crop of Co 997 planted with rayungans in May (18.43%) and harvested at 8 months in January was distinctly better in juice sucrose value than that of the normal crop harvested in December (17.54%) at 10 months age.

Climatic conditions that favour sugar accumulation are noted to be cool dry weather, low humidity and prevalence of low minimum

temperatures from about two to three months before the harvest of the crop. These conditions are observed to be experienced by crops planted during last week of May and July (or

say June-July) and harvested during January-March as can be seen from the meteorological data furnished in table -2.

Table—2.

Meteorological Data

Month	'Rainfall' in mm	No. of rainy days	'Maximum' temperature °c	'Minimum' temperature °c	Relative humidity%		No. of sunshine hours per day
					8.00 AM	2.00 PM	
January 77	Nil	Nil	30.2	16.3	89	50	9.3
February	Nil	Nil	32.0	17.6	91	51	9.9
March	Nil	Nil	34.8	21.3	85	49	8.9
April	64.8	5	34.8	24.8	84	58	8.5
May	236.0	9	34.9	25.4	85	62	8.8
June	198.8	8	34.8	26.1	85	65	6.4
July	79.5	9	32.8	25.5	88	68	4.4
August	109.9	8	32.9	25.7	88	67	3.3
September	83.8	7	33.3	24.9	87	61	5.7
October	183.4	7	32.4	22.9	89	64	8.4
November	191.6	10	30.9	22.3	90	65	5.9
December 77	0.8	Nil	29.3	17.5	84	44	9.0
January 78	38.6	3	29.2	17.2	89	48	8.1
February	22.8	1	31.1	18.2	88	47	9.1
March 78	14.0	2	33.9	20.5	88	44	9.6

1. The optimum time of planting for short duration crops of 8 months duration was noted to be June-July.
2. Rayungans were noted to be superior to settlings as seed material for such crops.
3. In respect of sugar yields CoA 7601 was found to be distinctly superior to Co 997.

However, it may be mentioned that CoA 7601 is highly susceptible to rust under natural conditions. So, it does not appear desirable to spread this variety on a large scale.

A variety with more or less similar cane yields and juice quality as CoA 7601 but free from rust incidence under natural conditions has to be selected if short duration crops are to be popularised.

June-July planted short term crops may be harvested in February-March and ratooned for harvesting in November-December. Prior to the planting of short term crops during the period January to May-June, it is possible to grow commercial crops like cotton or groundnut to compensate about 30% loss in cane yield due to adoption of short term cropping. These aspects are to be further studied in greater detail.

Relative merits of rayungans and settlings as seed material for short term crops

The mean per cent establishment of rayu-

ngans and settlings irrespective of time of planting and variety was 87.54 and 85.23 respectively and the values did not differ significantly. But rayungans (80978 per hectare) were noted to give significantly higher stalk population than settlings (75307 per hectare).

Rayungans were observed to have comparatively better developed shoots than settlings. Moreover, in rayungans produced on standing canes, sett root initials were noted to be dormant unlike in the case of settlings raised by planting single budded setts on the ground. When rayungans are planted in the main field, root initials were found to have been activated immediately and grew up to supply moisture and nutrients for the growing shoots leading to early tillering. Settling could not have this advantage because sett roots developed in the nursery itself and got damaged while lifting for transplanting in the main field. Thus better development of shoots in rayungans coupled with the advantage of undamaged roots for drawing moisture and nutrients in the initial stages appear to have led to early and higher tillering and stalk population at harvest in rayungans. Settling lagged behind apparently since they had to depend exclusively on the shoot roots which developed belatedly. Similarly the length of millable canes, cane yield and juice quality at harvest were distinctly better in crops raised from rayungans than those from settlings. The data are presented in table 5.

Though the crops planted in July and September and harvested at six months age in January and March respectively had experienced similar climatic conditions, they did not possess rich juice quality. This appears to be due to lack of minimum amount of vegetative development to take full advantage of the favourable conditions for accumulation of sugar. This minimum vegetative development seems to have been attained only when the crops were planted during the last week of May to end of July with 6 weeks old rayungans. Thus the minimum optimum physiological age appears to be $9\frac{1}{2}$ months.

Cane Yield

Among the crops that registered economic level of juice quality (over 18% juice sucrose with a minimum purity of 85%), those planted during last week of May and July in CoA 7601 gave 67.80 and 70.83 tonnes of cane yield per hectare. In Co 997, the cane yield of May planted crop which had a little over 18.0% juice sucrose gave 68.12 tonnes of cane yield per hectare.

The normal crops of CoA 7601 and Co 997 harvested in December at 10 months age registered 103.29 and 98.27 tonnes of cane yield per hectare. Thus the yields of short term cane crops with economic level of juice quality were noted to be about 65 to 70% of those of normal crops. The data are presented in table-3

Long days, short nights and heavy rainfall coupled with high humidities are noted to be conducive for rapid vegetative growth. Such climatic conditions prevailed from middle of

May to middle of November during the year as can be seen from the meteorological data furnished in Table 2. Crop planted in February and harvested in December had the full benefit of favourable climatic conditions that prevailed from middle of May to middle of November and gave maximum cane yields. For the crops planted in different months and harvested at 6 to 8 months age, the period of favourable climatic conditions was either shortened or the crops were not sufficiently aged (3 to 4 months) by the time the rainy season commenced to take full advantage of the climatic conditions to put on sufficient vegetative growth. This naturally led to lower cane yields.

Estimated Sugar Yield

The estimated sugar yields were found to be a little over 9.00 tonnes per hectare in CoA. 7601 crops raised with rayungans during March, May and July and harvested at 8 months age. Similarly May planted Co 997 crop using rayungans as seed material also gave over 9.00 tonnes sugar yield per hectare though it was inferior to that from CoA 7601. However, crops planted during last week of May and July (say June or July) had economic level of juice quality indicating that planting in June-July is optimum time for growing short term cane crops with remunerative sugar yields. Crops planted subsequent to July (September to November) and harvested at 8 months were observed to have not experienced favourable climatic conditions to give remunerative sugar yields. The data are presented in table-4.

Results presented in the foregoing pages indicate the following :

Table-5

Relative Merits of Rayungans and Settlings as Seed Material for Short Term Crops

Particulars	Rayungans	'Settlings'	'Difference' significant or not	't' observed
1. Establishment	87.54	85.23	No	2.004
2. Stalk population per hectare at harvest	80978	75307	Yes	3.120
3. Length of millable cane (cm)	194.6	187.6	Yes	2.999
4. Cane yield in t/ha	65.71	58.60	Yes	3.667
5. Percent juice sucrose	14.24	13.69	Yes	2.724
6. Glucose per cent	1.54	1.78	Yes	2.500
7. Estimated sugar yield in tonnes per ha.	6.67	5.53	Yes	7.303
't' from tables @ P=0.05				2.131

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EFFECT OF TREATMENTS WITH AZOTOBACTER CULTURES ON THE YIELD OF SUGARCANE IN VARYING AGROCLIMATIC CONDITIONS OF BIHAR

By

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ABSTRACT

Field trials located at seven wide spread sites in Bihar to study the effect of Azotobacter culture treatments on the yield of sugarcane revealed that generally culture treatments along with 35 kg. N/ha gave higher increase in yield per unit of N input. But the efficiency of the cultures, obtained from various sources, varied in different soils. Light textured soils rich in organic matter appeared to be better suited for bacterization with Azotobacter.

Introduction

The population of Azotobacter in cultivated tropical soils is generally low and varies widely depending mostly on the levels of organic matter and soil reaction (Rai *et al.*, 1976). The nitrogen fixing capacity of calcareous soils of North Bihar showed positive significant correlation with the Azotobacter population (Rai *et al.*, 1975). Though the claims for increase in yield due to bacterization with Azotobacter has been generally criticized (Brown, 1974) but soil inoculation studies carried out by Ahmad *et al.* (1977) indicated that suitable strains may be usefully tried for enrichment of soil nitrogen. In pot experiment bacterization with Azotobacter increa-

sed yield of sugarcane without any deterioration in juice quality (Ahmad *et al.*, 1976). In the present study, the cultures were further tried under field conditions to assess their efficacy in different agroclimatic regions of Bihar.

Materials and Methods

Field trials at seven sites in Bihar representing varying soil characteristics were conducted with four different Azotobacter cultures applied with 35 and 50 kg. N/ha in randomised block design. Culture I was locally isolated at Sugarcane Research Institute, Pusa and culture 2, culture 3 and culture 4 were commercial preparations and supplied by

Biofertilizer Co. Amar Hill, Saki Bihar Road, Bombay; Bafelab, Poona and Prem Nath Brothers, Mahmada, Pusa respectively. Compost @ 200 q/ha was applied to soil at the time of preparation of land. Phosphate and Potash @ 85 and 30 kg./ha respectively were applied as basal dressing. Nitrogen in the form of urea was applied in three split doses i.e. 1/3rd at planting, 1/3rd after two months and rest 1/3rd at four months after planting. The culture was also applied in two split applications. Half of the culture mixed with surface. Soil was applied to three budded sugarcane sets placed in furrows. Rest half of the culture well mixed in water was applied in the rootzone in the first week of July.

Results and Discussion

Application of *Azotobacter* culture at 35 and 50 kg. N/ha increased yield of sugarcane compared to non-inoculated control at all the seven sites (table 2). The increase in yield due to culture treatment at 35 kg. N/ha was maximum at Banmankhi (70 q/ha) followed by Riga (55 q/ha), Motihari (51 q/ha), and Majhaulia (41 q/ha). With 50 kg. N/ha, corresponding increases in yield at these sites were 60, 30, 87 and 42 q/ha respectively. Lower increase in yield due to culture treatment with 35 kg. N/ha was obtained at Motipur, Patna and Sidhwalia (20, 21 and 39 q/ha respectively).

This showed that culture treatment along with 35 kg. N/ha gave higher increase in yield per unit of N input at all the places except at Motihari where higher increase in yield per unit of N was recorded when the culture was applied with 50 kg. N/ha.

Efficiency of the cultures varied in different soils. In non-calcareous soil of Majhaulia, culture 2 proved to be superior to other cultures under test and recorded higher yield with 35 kg and 50 kg. N/ha (406.5 and 487.9 q/ha respectively). At Motihari, culture 1 recorded higher yield (447.8 and 559.5 q/ha with 35 and 50 kg. N/ha respectively). This culture proved superior to other cultures at Banmankhi also—and the yields with 35 and 50 kg. N/ha were 447.2 and 519.4 q/ha respectively.

These results indicated clearly the role of specific soil conditions on the effectiveness of the cultures. Light textured soils rich in organic matter appeared to be better suited for bacterization with *Azotobacter* as compared to the heavy textured soil of Patna.

Increase in yield, however, may not be solely due to nitrogen fixing activity of the cultures and other synergistic effect of bacterization might have also contributed towards increase in yield. Further experiments are in progress to evaluate critically the individual contribution of N-fixing activity or other synergistic effects, if any.

Table—1
Characteristics of Soils

Sl. No.	Location of Field trial	Texture	pH	Organic carbon %	Ca CO ₃ %	Total bacteria 10 ⁶ /g	Azotobacter 10 ² /g
1.	Majhauria	Sandy loam	7.8	0.714	8.6	4.2	13.0
2.	Riga	—do—	7.6	0.483	1.62	3.2	4.0
3.	Motipur	—do—	8.2	0.466	42.8	4.0	16.0
4.	Motihari	—do—	8.2	0.788	29.0	7.5	7.5
5.	Sidhwalia	—do—	8.4	0.606	28.2	6.8	6.0
6.	Banmankhi	—do—	7.6	0.655	Nil	5.2	6.0
7.	Patna	Clay loam	7.3	0.585	Nil	5.1	9.0

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Table—2

Effect of Treatment with Azotobacter Culture on the Yield of Sugarcane (Q/HA)

S.N.	Treatment	N (kg./ha)	Majhulia	Riga	Motipur	Motihari	Sidhwalia	Banmankhi	Patna	Mean.
T ₁	No. Azo. culture	70	369.7	403.9	499.1	531.9	480.3	504.3	531.9	475.2
T ₂	Culture 1	35	369.7	346.1	419.0	447.9	351.5	447.2	535.2	416.7
T ₃	Culture 2	35	406.5	400.6	413.7	400.6	334.3	420.3	535.2	419.9
T ₄	Culture 3	35	375.0	336.9	413.7	420.3	325.1	384.2	545.0	400.9
T ₅	Culture 4	35	376.3	346.1	419.6	419.0	384.2	454.4	535.2	419.7
	Mean (T ₂ — T ₅ only)		381.9	357.4	416.5	421.9	348.8	426.5	526.4	411.3
T ₆	No Culture	35	340.2	302.1	396.7	367.2	310.0	356.6	505.6	368.3
T ₇	Culture 1	50	434.1	384.2	480.7	559.5	482.0	519.5	528.6	484.1
T ₈	Culture 2	50	487.9	380.2	522.1	470.2	491.2	464.3	505.6	474.5
T ₉	Culture 3	50	437.4	373.7	487.3	433.4	433.4	423.6	505.4	443.1
T ₁₀	Culture 4	50	429.5	382.9	495.2	457.1	445.9	478.7	512.2	457.3
	Mean (T ₇ — T ₁₀ only)		447.2	380.2	496.3	482.0	463.1	471.5	512.9	464.8
T ₁₁	No Culture	50	405.2	350.0	463.6	395.3	384.2	411.8	519.4	418.5
	C. D. at 5%		19.11	14.36	19.52	20.51	18.83	18.18	23.52	19.15

SCALE INSECTS—A POTENTIAL DANGER FOR SUGAR INDUSTRY IN EASTERN UTTAR PRADESH

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ABSTRACT

Scale Insect (M. Glomerata) is considered a minor pest in India because it is absent in most of the north Indian sugarcane growing States. As regard its control measures are concerned and the damage occur due to the pest in sugarcane crop, it can be catagarised as a serious pest. Scale insect was first spotted during 1970—71 season in the cane areas of two sugar factories in East U. P. but no effective control measures were taken and the pest has spread up in the 18 sugar factories, cane areas in East U. P. In some of the sugar factories, the cane fields affected by the scale insects during 1977-78 season were in the range of 70 to 75%. The ratoon crop was found most infestated by the scale insects. Inspite of many representations from the sugar factories and findings of the research workers regarding seriousness of the pest, the concerned State Governmet Department has not taken any effective control measures of the pest which has caused great loss to the cane growers and the sugar factories in East U. P. The pest is likely to spread in the cane areas of the Central and the Western regions of the State.

Introduction :

Scale Insect (M. Glomerata) is a serious pest of sugarcane in India because it is difficult to control. It caused heavy damage to the crop both in its tonnage and sugar content. In the recent years, the pest has caused heavy damage in some pockets of Andhra Pradesh, Maharashtra, Gujrat, Madhya Pradesh, Tamil Nadu and Kerala. The attack of the pest

was so severe in Madhya Pradesh that the Jaora Sugar Factory remained closed for two years. During 1976, the scale insects attacked sugarcane crop in Vishakhapatnam district of Aandhra Pradesh and according to Dr. A. Reddy, Director of Extension, Andhra Pradesh Agricultural University, the pest spread like wild fire and a large area of the cane crop had to be burnt due to the severity of the infestation. Fortunately, the scale insect

pest was not known in the Northern States of Punjab, Haryana, Uttar Pradesh and Bihar in the past. The spot infestation of the pest were noticed in some parts of East U. P. sugar factories areas in 1971 but no notice was taken by the concerned department. The large scale infestation in five to six sugar factory areas was observed in 1974-75 season and since then it is increasing year after year and have spread up in the cane areas of 18 sugar factories in the region. Recently, some infection of the scale insect pest was noticed by the author at Bazpur Sugar Factory in Central U. P. and shown the same to the Chief Cane Development Adviser, Co-operative sugar factories in the State. The main reason for spreading up of the pest is that no effective control measures have been taken by the concerned department except advising the cane cultivators to do this and that. Though, it is already late but in case immediate control measures are not taken for this pest, the cane area of the Central and the Western regions of the State will also be not spared and both the cane growers and the sugar factories will suffer because the scale insects infestation reduces cane seed germination by 20-25%, cane weight by 15 to 20% and sugar in cane by even 50%.

What is Scale Insect, its Dissemination and nature of damage :

There are about 35 species of the scale insects reported by the Entomologists but *Malaspis Glomerata* (Green) is confined to India. These insects are black in colour, dome shaped and adhere to the nodal region of the cane stalks generally under the leaf sheaths. The insect hibernates in the winter under the black scale of the mother in first nymphal

stage. The female of the scale insect gives birth to as many as 400 pale yellowish crawlers at a time. The crawlers or the nymphs remain active for 12 to 25 hours and move about freely on cane stalk. These crawlers advance towards the growing apex and settle on an internode preferably at the spot which is succulent and protected by leaf sheaths. After settling, the nymphs start sucking cane sap. Subsequently, the nymphs become round in shape and change their colour from pale yellow to light ash and finally to blackish. At this stage, the formation of protective covering called 'scale' takes place and that is why the pest is called 'scale Insect'. With the growth of the insects, the covering gets bigger and thicker. A large number of colonies spreading over the entire internodes of the cane stalks with blackish dome shaped scales forming a thick incrustation on the rind can be seen on heavily attacked sugarcane crop. The female of the scale insect completes its development in 39-46 days while the male takes 18-28 days. There may be as many as 9 overlapping generations of the pest in a year. The female scales are more or less round and circular whereas the male scales are oval and oblong.

Scale insects mainly spread through the transport of cane seed material from the infested areas to new areas. They disseminate by sticking to the bodies of human beings and animals. Strong winds too carry them from field to field.

The attack of scale insects start after formation of some internodes in the cane plant. In the beginning, the infestation is confined to lower internodes but with the growth of the cane, it spreads to new internodes also.

Infestation of scale insects is mainly concentrated on the internodes which usually remain covered with leaf sheaths. The insects even in the nymph stage establish themselves on the cane stalk by deep penetration of their oral bristles or stylets in the stem. Desapping of cane through the stem reduces the vigour of the plant, the weight of the infested cane stem reduces while sugar % cane drops. In severe cases, the cane leaves are affected and further formation of the sugar is prevented.

Review of Earlier Findings :

The scale insect (*M. Glomerata*) is generally treated as a minor sugarcane pest by the Entomologists in India because it is absent in many sugarcane growing States. Though the pest is considered to be of minor importance, it sometimes assumes a serious form and causes considerable damage to the cane crop both in yield and sugar content. Further, it can be called as the most harmful insect amongst the different sucking type of insects of sugarcane as its control is very difficult. Tambhekar¹ noted reduction of 30-35% in cane yield and 40% in commercial cane sugar (C.C.S.) on account of scale insects attack in Surat district of Gujarat State. Raja Rao² observed the difference in C.C.S. between healthy and scale insects affected cane to be about 2 units. In Mauritius, a reduction of about 40% in sugar recovery from the scale insects affected

cane crop has been reported in 1959³. The author conducted a full scale mill trial of healthy and the scale insect affected cane supply during 1970-71 season at the Saswad Sahakari Sakhar Karkhana Ltd., Malinagar in Sholapur district of Maharashtra State and found 2.62% lower sugar recovery in the pest affected cane supply. The main reasons of the lower sugar recovery in the pest affected cane are the loss of sugar content as well as reduction in the juice % cane due to sucking. The fibre % cane increases abnormally high in the scale infested crop due to loss of the juice and thereby the loss in bagasse also increases reducing the sugar recovery.

Survey of Scale Insects Affected Cane area in East U. P. Sugar Factories :

The author has visited the cane areas of many sugar factories in Gonda, Basti, Gorakhpur and Deoria district of Eastern Uttar Pradesh during pre-harvest maturity survey during 1976-77 and 1977-78 seasons. A heavy infestation of scale insects in the cane fields of ratoon crop was observed in these sugar factories. As the sugar recovery remained low in some of the factories inspite of drawing cane supply on maturity basis and therefore the present investigation has been taken up. The information collected from the different sugar factories regarding the intensity of the pest is given at Table I.

Table-I

Showing intensity of 'Scale Insects' infestation in cane areas of
sugar factories in East U. P.

No.	Name of the Factory	First infestation reported season	Aprrox. % Cane area affected Ratoon/Plant		Cane Varieties affected
1.	Balrampur	1970-71	10.0	1.0	BO. 17 BO. 34 CO. 1158
2.	Tulsiपुर	1974-75	5.0	—	BO. 34 CO. 1158
3.	Motinagar	1976-76	12.0	3.0	BO. 17
4.	Walterganj	1976-77	1.0	—	BO. 17
5.	Anandnagar	1976-77	1.0	—	BO. 17 BO. 34
6.	Sardarnagar	1974-75	1.0	—	BO. 17
7.	Gauribazar	1976-77	2.0	—	BO. 14 BO. 17
8.	Baitalpur	1976-77	8.0	—	BO. 14 BO. 17 BO. 29
9.	Deoria	1976-77	2.0	—	BO. 14
10.	Lakshmiganj	1975-76	70.0	5.0	BO. 14 BO. 17 BO. 29
11.	Captainganj	1974-75	70.0	7.0	BO. 14 BO. 17
12.	Ramkola (P)	1976-77	50.0	5.0	BO. 70 BO. 14
13.	Padrauna	1974-75	75.0	10.0	BO. 17 BO. 14 BO. 17
14.	Kathkuiyan	1975-76	20.0	—	BO. 70 BO. 14
15.	Khadda	1976-77	7.0	—	BO. 17 BO. 14 BO. 17

The exact information regarding the Scale Insect pest infestation could not be obtained from other factories in the region.

The information given in the above table revealed that the pest was first spotted in Balrampur cane area during 1970 71 season and now it has spread in 18 sugar factories cane areas in the region because no effective control measures were taken by the State Cane Department. The infestation reported during 1976-77 season ranged from 1.0% to 75% mainly in the ratoon crops of the Bo cane

varieties though infestation was noticed in Co. 1158 variety at Balrampur sugar factory cane area. The severely pest affected cane crop was found completely dried and withered. The analysis of the Scale Insects affected cane as carried out in two sugar factories by the author has been found more alarming. The analysis results are given at Table II below :

Table II

Showing Analysis of the Scale Insects Affected and Healthy Cane Samples.

No.	Name of the Factory	Date of analysis	Condition of the sample	Ext. % can	Brix %	Purity
1.	Balrampur	26-11-76	Infested	19.0	17.47	72.58
2.	"	"	"	22.0	20.16	73.96
3.	"	"	"	25.4	15.74	72.11
4.	"	"	"	21.8	14.16	72.39
5.	"	"	"	24.8	17.69	75.52
6.	"	"	Healthy	46.0	18.64	84.23
7.	"	"	"	47.4	18.82	86.50
8.	"	"	"	48.0	20.56	84.53
9.	"	25-12-76	Infested	28.0	19.70	74.70
10.	"	"	"	30.5	20.20	68.44
11.	"	"	"	27.4	18.40	70.35
12.	"	"	"	28.0	17.40	72.40
13.	"	"	Healthy	40.6	19.22	86.70
14.	"	"	"	44.70	19.80	87.01
15.	"	28-1-77	Infested	24.20	33.30	72.48

No.	Name of factory.	Date of analysis	Condition of the sample	Ext % cane	Brix %	Purity
16.	"	"	"	28.0	13.18	79.82
17.	"	"	Healthy	42.5	19.40	86.40
18.	"	"	"	38.3	20.62	87.35
19.	Padrauna	5/12/76	Infested	30.3	14.30	71.80
20.	"	"	"	24.6	16.70	72.34
21.	"	"	"	22.1	16.33	74.88
22.	"	"	Healthy	38.40	18.99	84.80
23.	"	"	"	37.4	19.30	86.20
24.	"	"	"	37.8	19.55	86.80

The analysis results as given in the above table revealed an appreciable fall of juice % cane, Brix and purity of the Scale Insects affected cane as compared to the healthy cane samples. The fall in sugar content, however, depended on the intensity of infestation.

5. Conditions of the Scale Insects infestation in East U. P. Sugar Factories Cane area Duriag 1977-78

The year 1977-78 has been good season for the sugar factories in the state due to bumper cane crop and more availability of the cane to the sugar factories for crushing. However, a large areas in most of the sugar factories of East U. P. were severely affected by the scale Insects right from the begining.

This year, the cane growers of some of the factory areas like Padrauna, Captainganj, Lakshmiganj etc. were also worried due to infestation of their crop by the Scale insects. In the meantime, the East U. P. Sugar Mills Association has organised a Seminar on Scale Insects Infestation of the cane crop and its damage to draw the attention of the State Govt. The scientists from the Indian Institute of Sugar Cane Research, Lucknow and the Regional Sugarcane Research Station, Gorakhpur attended the seminar besides a large number of factories representatives. However, it was noted with concern that none of the officer like the Addl. Cane Commissioner (Dev). Joint Cane Commissioner of the Deputy Cane Commissioner Eastern Range has attended the seminar because actual

control measures for the pest cannot be executed without their help or rather these are the persons who are responsible for taking action to control the pest. Most of the speakers in the seminar expressed the concern about the gravity of the situation due to the scale insects infestation in the area stressed upon immediate action to be taken to control the pest. Some of the representatives from the sugar factories complained regarding supply of cane seed material infested with scale insects from the Research Station, Gorakhpur due to which the pest has been spreading in unaffected areas. The seminar was held in the month of June, 1977 but no control measure were taken by any agency and the pest spread up in more areas. A survey was conducted jointly by the Research, staff, local cane officials from the society and the factory authorities in the month of October, 1977 at the instance of the Minister for Cane Development of U. P. Government and about 45 to 55% cane fields of the ratoon cane crop were found affected by the scale insects in the cane areas of Padrauna, Captainganj and Lakshmiganj sugar factories. This clearly indicated the lack of interest and unresponsiveness of the concerned department officials towards the control measures for the pest to save guard the cane grower and the sugar factories from the huge loss.

6. Suggested Control Measures for Scale Insects and Their Limitations :

Scale insects are mainly spread through the transport of seed material from the infested areas to the new planting areas. They also disseminate by sticking to the bodies of human being and animals. Strong winds too carry

them from one cane field to another. The control measures for the pest being suggested to the cane growers by the departmental officials as well as the sugar factories staff are :

- a) Selection of healthy cane seed material for new planting.
- b) Avoid growing cane varieties susceptible to the pest and have enveloping leaf sheaths.
- c) Dipping the cane setts before sowing in 'Aldrine or Malathion'.
- d) Dig out the stubble after harvest and burn them along with cane trash.

It is suggested that instead of giving the control measures to the poor-cane growers who have very limited resources, the control should be carried out by the department and the sugar factories themselves. There is a big Sugarcane Seed Corporation in the State where the prime duty is to distribute healthy cane seed material among the cane growers. The corporation should look after the a, b and c-suggested control measures. Further, the system of cane supply in the State is such, that the entire cane crop of the pest affected cane field is not harvested at a time but the same is carried over for months together. In these circumstances, how it is possible to burn the part of the field after digging out the stubbles. The pest is migrated from the partly harvested cane field easily. As such, it is suggested that the Departmental officials like the District Cane Officer, or Senior Cane Development Inspector or the Cane Protection

Inspector should visit the scale insects infested cane fields and arrange to supply the entire crop in the factory as early as possible by issue of special cane harvesting purzies. Thereafter, the stubbles should be dug out and burn alongwith the cane trash in the presence of a responsible officer like the Cane Development Inspector or the Cane supervisor.

Scale Insect pest has been completely controlled biologically in Mauritius and necessary expertise may be obtained in this respect from that country. The biological control measures at present being undertaken at the Biological control Laboratory, Gorakhpur is very slow and in preliminary stage. Further, the Deputy Cane Commissioner, Eastern Range should be made responsible to provide all necessary facilities like the transport and the cane fields to the staff of the Biological Control Laboratory to carry out their experiments to control the pest.

7. Conclusion

The sugar productivity per unit area in East U. P. sugar factories is the lowest in the country due to poor cane yield and low sugar

recovery. Further, the factories are not getting cane for the full crush of atleast 150 days which results high cost of sugar production. The infestation of scale insect pest has further, aggravated the conditons in the last 3 to 4 years. It is suggested that the State Cane Department should start the control measures for the pest on war footing even bypassing some rules and regulations in force for the cane supply in the factories. The sugar factories and the cane growers in the region will automatically co-operate in this programme once the local field staff under the direct guidance of the senior officer of the department are determined to eradicate the pest in a specified time.

Acknowledgement

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IS EARTHING UP NECESSARY FOR ADSALI SUGARCANE ?

By

J. D. Chougule¹ and B. R. Patil²

ABSTRACT

Field experiments were conducted at Tilaknagar Sugarcane Farm during 1971-72 and 1972-74 to find out the effect of earthing up on 'adsali' sugarcane crop variety Co-740. Earthing up with human labour and bullock labour were compared with no-earthing up. The height of cane, number of internodes/cane was maximum in case of no-earthing up. The yield of sugarcane/ha was reduced due to earthing up and was maximum in case of earthing up by human labour.

Sugarcane is one of our most important food-cum-cash crops, providing employment to a large number of people in addition to contributing to foreign exchange earnings. It occupies about 2.6 million hectares and is grown under varied agro-ecological conditions. The area under sugarcane in Maharashtra is only 8 percent of the total hectarage in the country but it claims more than 27 percent of the total sugar production in the country. Even though Maharashtra is at the forefront of the sugar production, the cost of production is increasing day by day. Unless the cost of production is decreased the sugarcane growing will not be profitable. The labour required for sugarcane cultivation is probably the highest as compared to other crops. With the introduction of sugar factories in the rural areas, the labour availability has been decreased and the cost

of labour is increased. Feeler trials with and without earthing up did not show any appreciable effect of earthing up. (Anonymous, 1957). Clement (1959) states that earthing up is not necessary for Sugarcane. Chinchorkar (1970) observed that the earthing up reduced the cane yield by about 6 t/ha. the cultivators on the other hand, believe that earthing up increases the cane yield. The operation of earthing up substantially contributes to the cost of cultivation and hence it was worthwhile to study the effect of earthing up on sugarcane.

Materials and Methods

The field experiments were conducted at the Maharashtra Sugarcane Farm Tilaknagar, Dist. Ahmednagar (Maharashtra) during the years 1971-72 and 1972-74 on heavy black soils. Three treatments viz. earthing up

with human labour, — earthing up with bullock labour and no earthing up were taken in Randomised Block Design replicated seven times. The net plot size was 20 gunthas. The crop was *adsali* in both the years. During first year it was planted on 20th July, 1971 and harvested on 15th December, 1972. In second year the cane was planted on 23rd July, 1972 and harvested on 3rd January, 1974. The fertilizers were applied @ 450 kg. N, 150 kg. P_2O_5 and 150 kg. K_2O /ha, through urea, single superphosphate and muriate of potash respectively. The cane yield and the yield attributing characters were studied.

Results and Discussions

The data on the height of millable cane, number of internodes per cane, weight of individual cane recorded at the time of harvest are presented in Table-1 and the total number of canes/ha and the yield of millable canes/ha are presented in Table-2. It would be observed from Table-1, that the height of millable cane was maximum in both the years in the plots where no earthing up was done. The number of internodes per cane, though did not differ significantly was also more in case of no earthing up treatment. This has obviously resulted in higher weight of individual cane. The data in Table-2 reveals that the number of canes/ha were higher where no earthing up was done.

This indicated that there were less effective tillers in plots where earthing up was done either by human or bullock labour. This may be due to the damage done to surface roots. As a result of this the cane must have received a set back which has even resulted in reduction in yield. There was significant increase in the yield of millable cane in second year where earthing up was not done as compared to the other two treatments. There was about 11% reduction in the yield of cane when earthing up was done by human labour. However, the reduction was very insignificant (i.e. only about 2 t/ha) when earthing up was done by bullock power. The yield attributing characters such as number of millable canes, weight of individual cane, height of cane etc., were all adversely affected by earthing up and hence it also reflected in the ultimate yield. Clement (1959) also observed that the earthing up is not advantageous for sugarcane. Chinchorkar (1970) observed reduction in the cane yield due to earthing up. However, he claims that earthing up facilitated uniform application of irrigation water and reduction in lodging of cane. But if this does not improve the yield, on the other hand reduces the yield to the extent of 6 to 15 t/ha, it will be worthless to carryout earthing up and increase the cost of cultivation and at the same time sacrifice the yield.

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Table—1
Height of millable cane (cm) number of internodes/cane
and weight of individual cane (Kg) at harvest.

Treatment	Height of millable cane Cm.			Number of internodes/ cane.			Weight of individual cane (Kg)		
	1971-72	1972-74	Mean	1971-72	1972-74	Mean	1971-72	1972-74	Mean
Earthing up by human labour	295.30	266.59	280.94	35.00	34.90	34.95	1.500	1.651	1.575
Earthing up by bullocks	303.30	271.43	287.36	35.57	34.30	34.93	1.571	1.702	1.661
No earthing up	312.30	273.44	292.86	36.14	34.00	35.07	1.643	1.681	1.612
F Test	N. S.	N. S.	—	N. S.	N. S.	—	N. S.	N. S.	—
S. E. $\pm$	16.96	8.74	—	1.69	0.62	—	0.1156	0.837	—
Q. D. at 5% level	—	—	—	—	—	—	—	—	—

(N. B. : N. S.—Non significant)

Table-2
Number and yield of millable canes/ha

Treatment	Number of millable canes/ha			Yield of millable canes/ha (t/ha)		
	1971-72	1972-74	Mean	1971-72	1972-74	Mean
Earthing up by human labour.	93,962	1,05,350	99,656	152.20	173.25	167.72
Earthing up by bullocks	1,01,642	1,07,850	1,04,746	167.10	183.12	175.11
No earthing up	1,03,785	1,11,425	1,07,605	169.40	186.86	178.12
F Test	N. S.	N. S.	—	N. S.	S	—
S. E. +	6074.98	3888.50	—	13.39	5.95	—
C. D. at 5% Level.	—	—	—	—	12.97	—

(N. B. : N. S.—Non Significant S. Significant)

CORRELATION AND PATH COEFFICIENT ANALYSIS IN EARLY MATURING GENOTYPES IN SUGARCANE (*S. OFFICINARUM* L.)

By

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ABSTRACT

Twenty one early maturing genotypes were studied for 4 important quality characters i.e. brix per cent, sucrose per cent, purity coefficient and commercial cane sugar% (CCS%). Enough genetic variability existed in the present material. Significantly high and positive association was observed between C.C.S.% and other quality characteristics. Brix per cent contributed much more towards C.C.S.% both directly and indirectly. Sucrose per cent and purity coefficient had effect via brix per cent.

Introduction

The quality of sugarcane is of greatest significance in the economic growing of crops. It indicates the relative proportion of sucrose and other soluble solids in cane juice. Sugarcane varieties differ in their ripening periods and juice quality according to their genetic potentialities.

With the advent of hybridization programme in sugarcane enough genetic variability exists for most of the traits of economic importance. The available variability has not been fully utilized in this crop. The present studies on the association of various important quality characteristics and their pathways is an effort in this direction.

Materials and Methods

Twenty one early genotypes chosen for these studies were from diverse sources that included foreign, tropical and sub-tropical clones. The experimental material was planted in February 19, 1976 in a randomized block design with four replications. All the important quality characters were recorded during the month of December. The simple correlations were calculated by standard procedure outlined by Panse and Sukhatme (1958) and Path coefficient analysis was worked out according to method given by Wright (1921).

Results and Discussions

The range and mean values for all the four quality characteristics studied are given in Table

1. The mean square due to genotypes were significant for all the characteristics indicating there by the presence of genetic variability for all the characteristics in the present material and advocates the scope for improvement through selection.

All component characteristics i.e. Brix per cent, sucrose per cent and purity coefficients were significantly and positively correlated with commercial cane sugar (C. C. S.). Significant positive association was observed between brix per cent and sucrose per cent and brix and purity coefficient as has been reported by Mangelsdorf (1935). Sucrose, however, had no correlation with purity coefficient in this study.

In order to obtain a clear picture of the inter-relationship among different characteristics the direct and indirect effects of the important qualitative characteristics on the commercial canesugar (C.C.S.) were worked out separately.

(Table 2). The direct effects of brix per cent on C. C. S. were positive and high as compared to others. The indirect effect via sucrose and purity was negative. Sucrose on the other hand had negative direct effect on C. C. S. Sucrose otherwise is highly and positively correlated with C. C. S. Moreover, its indirect contribution was negative via purity coefficient thus brix per cent seems to be a very reliable component character. Sucrose is useful in the sense that it is highly and positively associated with C. C. S. The indirect effects of sucrose via brix is highly positive. Purity coefficient had negative direct contribution but indirect effects via brix were highly positive. Considering the direct and indirect effects of each of the component characters it became clear that brix per cent has high positive direct effects. It is, therefore, imperative for a plant breeder to give maximum weightage to brix values for quality breeding programme at least in early testing stages.

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Table—1

Range of Variability for Different Quality Characters in Early maturing Genotypes of Sugarcane

Characters	Range	Mean	MS (Genotypes)
Commercial cane Sugar (CCS)	8.11-11.47	9.67	3.58*
Brix per cent	15.42-20.18	17.62	4.94*
Sucrose per cent	12.56-17.00	14.52	6.26*
Purity (Coefficient)	78.70-85.63	82.30	9.00*

* Significant at 5% level

Table—2

Path Coefficient Analysis of C. C. S. VS Other component Characters and Simple Correlations

Character	Effect via			Simple correlations		
	Brix	Sucrose	Purity	Sucrose	Purity	CCS
Brix per cent	2.1840	1.1214	-0.1214	0.98*	0.46*	0.94*
Sucrose per cent	2.1403	1.1443	-0.0159		0.06	0.98*
Purity coefficient	1.0046	-0.0686	-0.2665			0.67*

* Significant at 5% level

RELATIVE PERFORMANCE OF DIFFERENT CANE VARIETIES IN THE LOW LYING AREA (KHADDAR) OF MAWANA DISTT. MEERUT

By

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ABSTRACT

A two years' varietal trial was carried out in the low lying area during 1975-76 and 1976-77 to find out the suitability of a cane variety for Khaddar area. The variety Bo. 70 has been found to be better for sugar production per hectare followed by Co. 6613 and Bo. 72 varieties in low lying areas of Mawana Sugar Works, Mawana Distt. Meerut.

Introduction

New sugar cane varieties are released every year and they are tested for their suitability for further propagation in the larger areas, keeping in view the climatic condition and type of soils in different zones.

In the varietal improvement projects of Mawana, Distt. Meerut special emphasis is being laid on development of varieties combining cane yield and sugar to a high degree taking into consideration the interest of the growers and millers

In Mawana zone 35% of the cane growing area is concentrated on the bank of river ganges. In this area more than 80% of the

cane crop is subjected to submergence and water logged conditions during rainy season.

In this area, Bo. 54 variety is the dominant variety and it is an early maturing variety. The performance of this variety was not upto the mark. Both yield and quality deteriorate after January. The other variety Co. 1148 has now started showing signs of deterioration due to susceptibility to Red Rot (*Collectotrichum falcatum*) in low lying area of Mawana. Therefore, the cultivation of cane under low lying conditions has created a problem for its substitute. This resulted in a set back for availability of good quality cane on the whole in khaddar area.

New varieties were therefore tried for a period of 2 years in this area and a good deal of success has been achieved. The performance of 6 promising cane varieties viz. Co.S. 687, Co. 6613, Co. 62399, Bo. 70, Bo. 72, Co. 1148 with the dominant variety Bo. 54 selected under this trial in the low lying area of the zone is discussed in this paper for 1975-76 and 1976-77.

Materials and Methods :

Investigations were undertaken on 6 sugarcane varieties with Bo. 54 (Standard variety) to determine the suitable variety of low lying area of Mawana zone. The layout was in the randomised block design with 4 replicates at grower's field. The net plot size was 6.30×13 Mtrs. The soil was sandy loam with average fertility and better water holding capacity.

Three budded sugarcane healthy setts were planted in well prepared fields during the month of February. The fresh setts were treated with agallol. BHC dust 10% was also used to avoid the attack of pests to the setts at the time of planting.

The planting was done in rows made 90 cms. apart for all the varieties. Nitrogen was applied at the rate of 125 Kg/ha through urea as a basal dose. The crop was raised as per usual practice and hoeings weeding earthing etc. were done frequently in all the plots alike.

The data on germination, tillering millable canes yield and juice quality viz. Brix, Pol, Purity expected recovery and commercial cane sugar (C. C. S.) per ha. were collected in both the years.

Results & Discussions

The result of the two years for germination tillering, millable cane are presented in table 1.

Germination

A critical examination of the table reveals that all the varieties gave more or less similar germination in first year. However, in second year variety Co. 62399 gave comparatively poor germination. This was due to the fact that all the cane seed were utilised from low lying area in second year of planting. Out of the rest, variety, Co. 62399 could not give better germination because of its non-suitability to the existing soil conditions.

Tillering

From the data, it is clear that during the first year COS. 687 and Co. 62399 gave comparatively higher tillers while in second year lower tillers were observed.

Millable Cane & Yield MT/Ha

It is evident from the data presented in the table that during the first year variety Bo. 70 and Co. 6613 gave the lowest number of millable canes per hectare while the yield were comparatively higher indicating thereby that the weight of individual sticks were more.

In the second year, variety Co. 62399 gave the lowest millable canes and the yield was also low. This is because of soil and climatic condition of the place which effect the variety (Devaraj *et al.*, 1973, and Zende 1970) sugarcane varieties differ considerably in their physiological behaviour yielding potentiality and peak maturity period.

Juice Analysis

The comparative data of Brix, Pol, Purity and expected recovery were assessed every month from October to January every year and presented in the table 2. The result revealed that variety CoS. 687 gave the lowest recovery in both the years.

Sugar M. T Per Hectare (C C.S.)

The final yield of cane per hectare was calculated from the expected recovery. The relevant data are summarised in the table 3.

From the data it was observed that variety CoS. 687, Co. 1148 and Co. 62399 are poor in the sugar per ha while Bo. 70 variety gave the maximum sugar followed by Bo. 54, Co. 6613 and Bo. 72. This was due to higher sugar accumulation and better yield.

Conclusion

From the study of 2 years trial of different cane varieties in the Khaddar of Mawana zone it is clear that Bo. 54 cane variety can be suitably replaced by Bo. 70 variety. This is clear from the observation recorded in respect of yield and sugar quality of 6 variety.

Acknowledgement

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Thanks are also due to the staff of Sugar Cane Research Station, Muzaffarnagar and Shajahanpur who have helped in making seed of these varieties available for experiments.

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Table—1

Comparative data for two year Average of W.T. of cane stick, Germination, Tillering, Millable Cane Yield

Varieties	1975 — 76			1976 — 77			Yield M.T./ ha.			
	Av. Wt. of sticks (gm.)	Germination %	Tillers/ ha. sticks	Millable cane per ha.	Yield M.T./ ha.	Av. Wt. of sticks (gm.)		Germination %	Tillers ha.	Millable cane per ha.
COS. 687	740	57	189162	97075	49.5	753	33	97600	80850	50.9
CO. 6613	900	52	179987	77892	60.5	865	36	24825	92650	52.8
Co. 62399	658	53	189666	86968	52.2	637	25	89555	71150	42.3
Bo. 70	884	42	147317	82355	62.5	870	43	135600	102687	67.8
Bo. 72	660	49	146410	87573	58.5	760	40	106938	76200	60.5
Co. 1148	700	45	208422	82943	50.8	726	45	154687	117200	52.4
Bo. 54	778	57	227480	98010	56.3	820	39	116250	94952	58.2

Table—2

Comparative data of juice analysis results for two years

Particulars	CoS 687	Co 6613	Co 62399	BO 70	BO 72	Co 1148	BO 54
OCTOBER 1975-76							
Brix	20.14	17.33	18.13	16.33	15.86	15.86	— at the foot of the table
Pol	17.93	15.13	15.56	13.36	13.26	13.01	—
Purity	89.02	87.30	85.82	81.81	83.66	82.03	—
* Recovery	12.04	9.80	14.74	8.38	8.30	8.10	—
NOVEMBER							
Brix	20.36	18.72	18.26	17.62	18.26	17.36	20.46
Pol	17.51	15.73	15.19	15.17	13.35	13.88	18.02
Purity	86.00	84.03	83.13	86.09	83.13	79.95	88.07
* Recovery	11.70	10.28	9.85	9.83	8.38	8.80	12.11
DECEMBER							
Brix	21.44	18.52	16.72	17.72	18.72	18.72	19.09
Pol	18.54	16.07	13.71	15.80	15.97	15.00	16.53
Purity	86.44	86.77	82.00	89.16	85.31	80.12	86.58
* Recovery	12.53	10.55	8.66	10.34	10.47	9.70	10.92
JANUARY							
Brix	19.22	19.82	19.49	19.99	19.49	20.12	21.92
Pol	16.14	17.63	16.68	17.03	16.68	16.71	19.52

Contd...

Particulars	CoS 687	Co 6613	Co 62399	BO 70	BO 72	Co 1148	BO 54	Remarks
Purity	83.97	88.95	85.58	85.19	85.58	83.05	89.05	
* Recovery	10.61	11.84	11.04	11.32	11.04	11.06	13.31	
OCTOBER								
1976-77								
Brix	14.16	16.96	16.95	19.94	15.56	14.96	16.36	
Pol	10.37	13.81	14.40	16.97	12.67	11.02	13.43	
Purity	73.23	81.42	85.05	85.10	81.42	73.66	82.09	
* Recovery	5.99	8.74	9.22	11.27	7.83	6.51	8.44	
NOVEMBER								
Brix	17.82	17.90	17.76	20.06	17.00	18.60	17.92	
Pol	13.72	14.75	15.41	17.99	14.29	14.42	14.88	
Purity	76.99	82.40	86.77	89.68	81.19	78.60	83.03	
* Recovery	8.67	9.50	10.02	19.09	9.13	9.39	9.60	
DECEMBER								
Brix	19.56	20.39	19.49	20.20	18.52	19.49	18.34	
Pol	16.82	18.69	16.99	16.80	15.24	15.91	15.32	
Purity	85.99	91.66	87.17	83.16	82.28	81.63	83.15	
* Recovery	11.15	12.65	11.29	11.14	9.89	10.42	9.95	
JANUARY								
Brix	18.32	20.12	20.00	20.40	18.89	18.67	18.56	
Pol	15.04	16.93	18.50	16.80	16.26	15.15	16.46	
Purity	82.10	84.14	92.50	82.35	86.49	81.14	88.69	
* Recovery	9.73	11.24	12.50	11.14	10.70	9.82	10.86	

Table—3
Sugar M. T. (C. C. S.) Per Hectare

Varieties	1975 76	1976-77	Average
CoS 687	5.25	4.95	5.10
Co 6613	7.16	5.93	6.54
Co 62399	5.76	5.33	5.54
BO 70	7.07	7.55	7.31
BO 72	6.45	6.47	6.46
Co 1148	5.61	5.15	5.38
BO 54	7.49	6.32	6.90

EFFECT OF BACTERIZATION WITH *AZOTOBACTER* AND *BACILLUS MEGATERIUM* ON THE YIELD AND JUICE QUALITY OF SUGARCANE IN CALCAREOUS SOIL

By

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ABSTRACT

Bacterization with two strains of Azotobacter Chroococcum and Azotobacter agilis in combination with 35 Kg N/ha improved the yield and juice quality of sugarcane significantly in calcareous soil of North Bihar. Mixed culture of Azotobacter was equally effective in these respects, N-fixing capacity of the cultures in liquid medium, however, did not appear to correlate with their effectiveness in soil. Bacillus megaterium was found effective in improving the yield and juice quality of sugarcane when applied with Azotobacter chroococcum (S₁) and Azotobacter agilis but it remained ineffective when applied with Azotobacter Chroococcum (S₂). Fifty percent economy in fertilizer-N was indicated due to the use of above cultures.

Introduction

The effect of bacterization with azotobacter and phosphate solubilizing organisms varies with crops and soil environment (Negreanu *et al.* 1960 and Brown, 1974). Increase in sugarcane yield was earlier reported with Azotobacter treatment in calcareous soil of North Bihar (Ahmad *et al.* 1976). In acid red loam soil of Kanke, *Bacillus megaterium* increased the yield and P uptake of gram (Ahmad and Jha, 1977). The present study was undertaken to investigate the effectiveness

of *Bacillus megaterium* with different strains of *Azotobacter Chroococcum*, *Azotobacter agilis* and mixed culture of *Azotobacter chroococcum* and *Azotobacter agilis* for bacterization of sugarcane in a sandy loam calcareous soil of North Bihar.

Materials and Methods

The efficacy of four cultures of *Azotobacter* with and without *Bacillus megaterium* was tested in a pot experiment in sandy loam calcareous soil of Pusa having pH 8.4, CaCO₃

24.5% and organic carbon 0.435%. The N-fixing capacity of the cultures was assessed in Ashby's mannite solution and phosphate solubilizing capacity of *Bacillus megaterium* was assessed in Pikovskaia's medium in 14 days at 30°C. Details of the treatments are mentioned in Table-2.

Phosphate and potash were applied in full at the time of planting. N. was applied in three split doses i.e., 1/3rd at planting, 1/3rd two months after planting and the rest 1/3rd four months after planting. One budded healthy germinated setts of sugarcane were planted in pots after treatment with respective cultures so as to give a uniform inoculum of 800 million viable cells of each culture to each sett. A similar dose of culture was applied three months after planting.

The moisture was maintained at about 2/3rd of the water holding capacity with sterile water. The crop was grown to maturity and yield and juice quality were determined.

Results and Discussions

The nitrogen fixing capacity of different *Azotobacter* cultures and the phosphate solubilizing capacity of *Bacillus megaterium* have been recorded in Table-1. The nitrogen fixing capacity of *Azotobacter chroococcum* (S₁ and S₂), *Azotobacter agilis* and mixed culture in Ashby's mannite solution were 11.6, 9.9, 8.5 and 10.5 mg N/g C respectively. *Bacillus megaterium* solubilized 191.5/u g P/ml. in Pikovskaia's medium in 14 days at 30°C.

The yield and juice quality of sugarcane have been recorded in table 2. A perusal of the data showed that the yield of sugarcane

at 35 Kg N/ha was only 1.39 Kg/pot. But application of *Azotobacter* culture in combination with 35 Kg N/ha could increase the yield (Varying from 1.61 Kg/pot to 1.89 Kg/pot) of sugarcane to the level of that produced by applying 70 Kg N/ha through urea. This suggested a fifty percent economy in fertilizer-N due to the use of *Azotobacter* Culture. The data further revealed that in the soil under study, *Azotobacter chroococcum* (S₁) and *Azotobacter agilis* were less effective as compared to *Azotobacter Chroococcum* (S₂) and the mixed culture.

Azotobacter Chroococcum (S₁) with higher efficiency of N-fixation (11.6 mg N/gC) was less effective in increasing the yield (1.65 Kg/pot) as compared to mixed culture (1.89 Kg/pot) with comparatively lower N-fixing efficiency (10.5 N/gC). This suggested that the efficiency of *Azotobacter* as bacterial fertilizer may not be solely due to its N-fixing capacity. Brown (1974) has also reported that effectiveness of *Azotobacter* cultures as bacterial fertilizers might be due to the production of biotic substances by the organism around the germinating seeds which may accelerate plant growth and substantially contribute to the increased yields.

Application of *Bacillus megaterium* along-with cultures of *Azotobacter chroococcum* (S₁) and *Azotobacter agilis* increased the yield (1.87 Kg/pot) as compared to the yields (1.65 Kg/pot. and 1.61 Kg/pot respectively) obtained with cultures in absence of phosphate solubilizing organism. However, when *Bacillus megaterium* was applied with *Azotobacter chroococcum* (S₂) or mixed culture it did not bring about any significant change in the yield.

A perusal of the data on juice quality revealed that the use of *Azotobacter* cultures along with *Bacillus megaterium* improved the juice quality of sugarcane. This may be due to solubilization of P by *Bacillus megaterium* resulting into better absorption of P by plants and increased concentration of sugar in juice. *Azotobacter Chroococcum* (S₂), however, could improve juice quality significantly even

without phosphate solubilizing organism.

Thus, the results indicated that *Bacillus megaterium* may be used with *Azotobacter chroococcum* (S₁) or *Azotobacter agilis* for bacterization of sugarcane in calcareous soil of North Bihar. Use of *Azotobacter chroococcum* (S₂) may be equally effective even without *Bacillus megaterium*.

Table-1

Nitrogen fixing and Phosphate solubilizing capacities of different organisms.

Sl. No.	Microorganisms	N. fixing capacity mg N/g C.	P-solubilizing capacity/ ug P/ml.
1.	<i>Azotobacter Chroococcum</i> (S ₁)	11.6	—
2.	<i>Azotobacter Chroocuccum</i> (S ₂)	9.9	—
3.	<i>Azotobacter agilis</i>	8.5	—
4.	Mixed culture of Sl. Nos. 1, 2 and 3.	10.5	—
5.	<i>Bacillus megaterium</i> .	—	191.5

Table-2

Effect of Bacterization with *Azotobacter* cultures and *Bacillus megaterium* on the yield and juice quality of sugarcane.

Treatments	Yield Kg/pot.	Brix	Pol %	Purity
A. Uninoculated control				
(i) N:P ₂ O ₅ : K ₂ O, 70 : 85 : 30 Kg/ha.	1.89	18.0	15.7	87.6
(ii) N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.39	16.6	13.9	83.7
B. Inoculated with <i>Azotobacter</i> without <i>Bacillus megaterium</i>				
(i) <i>Azotobacter chroococcum</i> strain + N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.65	18.6	15.7	86.2
(ii) <i>Azotobacter chroococcum</i> strain 2 +N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.89	20.0	17.4	85.9
(iii) <i>Azotobacter agilis</i> + N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.61	18.0	16.0	89.6
(iv) Mixed culture of B (i), (ii) and (iii)+ N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.89	19.0	16.4	86.4
C. Inoculated with <i>Azotobacter</i> alongwith <i>Bacillus megaterium</i>.				
(i) <i>Azotobacter chroococcum</i> strain 1 +N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.87	20.2	17.3	85.7
(ii) <i>Azotobacter chroococcum</i> strain 2 +N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha	1.80	19.5	17.2	88.2
(iii) <i>Azotobacter agilis</i> .+ N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.87	19.3	17.4	86.8
(iv) Mixed culture of C (i), (ii) and (iii)+ N:P ₂ O ₅ : K ₂ O, 35: 85: 30 Kg/ha.	1.82	20.4	17.5	85.6
C. D. at 5%	0.10	0.20	0.82	0.18

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"STUDIES ON THE EFFECT OF NITROGEN AND MOISTURE REGIMS ON YIELD AND QUALITY OF SUGARCANE"

By

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ABSTRACT

The nitrogen levels, moisture regimes and interaction between nitrogen levels and moisture regimes influenced positively and significantly the sugarcane plant height, number of tillers, millable canes, millable cane height, girth of cane and all these yield contributing attributes contributed to the cane yield. Beyond 200 Kg N/ha, the adverse effect of nitrogen on commercial cane sugar yield (CCS) was noticed when the influence of nitrogen alone was considered. However, the interaction between nitrogen and moisture showed significant additive positive effect on cane and sugar yields when higher doses of nitrogen fertilizer were coupled with lower soil moisture depletion regimes while its effect especially on CCS yield influences adversely when highest doses of nitrogen fertilizer (300 Kg N/ha) was accompanied by higher soil moisture depletion regime (75% ASMD). The highest nitrogen level (300 Kg N/ha) and lowest soil moisture regime (25% ASMD) combination treatment recorded not only the highest cane (134.6 tonnes per ha) and CCS (16.25 tonnes per ha) yields but also showed the greatest effectiveness in utilising the consumptive use of water (E_t). This was evidenced by the highest E_t/E_o ratio, water use efficiency (W. U. E.) and lowest evapotranspiration ratio (E. T. R) in this interaction treatment (300 Kg N/ha under 24% ASMD) as compared to all other treatments. The highest correlation between nitrogen percentage in (3 to 6 leaf laminae and cane and sugar yields was observed on 95th day of the crop-age indicating the importance of application of nitrogen fertilizer before 95th day of the crop-age so as to enable the plant to, develop the necessary infrastructure. The present investigation also showed that under low soil moisture availability conditions, it is necessary to limit the nitrogen application rate because higher application of nitrogen did not promote more growth and sugar formation than the available soil moisture can sustain. On the other hand, the rate of nitrogen application under high soil moisture conditions, should be adjusted to enable the plant to make full and efficient use of favourable soil moisture conditions to express its full yield potential.

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Introduction

India ranks first in sugarcane acreage in the world and 13th in respect of efficiency of cane production. Sugarcane yields vary tremendously due to many factors like soil fertility status, irrigation practices, control of weeds, pests and diseases. Agro-ecology of the region also plays a considerable role in determining cane productivity of the several factors, Nitrogen fertilizers and soil moisture have the greatest effect on sugarcane yields. According to Arnon (1972), basic problem in plant nutrition is that of adjusting moisture in exploiting plants, productivity potential. Lakshmikantham (1973), reported that increased levels of nitrogen fertilization had to be associated with increased frequencies of irrigation to realise higher cane and sugar yields. This type of inter-related approach is most essential for economising fertilizers and irrigation water while maximising the cane and sugar production. Keeping the above salient research finding the present investigations were designed to get information on nitrogen and soil moisture interaction for sugarcane crop on sandy loam soils of Hyderabad region.

Review of Literature

Higher application of nitrogen associated with higher levels of moisture realised higher cane yields (Suraj Bhan 1964, Srinivasan 1965 and Singh et al 1971). Experiments at Anakapalli (Anon, 1965, 1973, 1974) showed

that higher application of nitrogen coupled with lower levels of moisture affected adversely the sucrose per cent in juice as compared to higher application of nitrogen accompanied by higher levels of moistures. Lakshmikantham (1973) showed that maximum yield was obtained when higher doses of nitrogen were associated with higher levels of irrigation.

Materials and Methods

Site

The experiment entitled 'Studies on the effect of seven nitrogen levels and three moisture regimes on the yield and quality of sugarcane crop' was conducted at agricultural college farm, Rajendranagar, Hyderabad from March 1976 to March 1977, which represented the typical sandy loam nature of the soils.

Climate

The trends of different climatic parameters are depicted in fig. 1. The season in general was favourable to the crop growth.

Soil

Composite samples drawn at random from 0 to 60 cm. soil layers from the experimental field were analysed for the following physical and chemical properties as per the methods outlined by Piper (1957) and Jackson (1962) respectively.

Physical Properties

Course sand	... 78.86%
Fine sand	... 2.00%
Silt	... 4.00%
Clay	... 18.14%

Textural class ... Sandy loam

Chemical Properties

pH	... 7.2
E.C.	... 0.05 m. mhos/cm ³
Total Nitrogen	220 kg/ha
Available Phosphorus	... 27.1 kg P ₂ O ₅ /ha
Available Potassium	... 285 kg K ₂ O/ha
Organic matter	0.57%

Single Value Soil Moisture Constants

	Soil depth (cm)		
	0.15	15.30	30.60
i) Field moisture capacity at 0.3 atmosphere tension (pressure plate)	13.30	12.95	12.43
ii) Wilting coefficient (%) at 15 atmosphere tension. (pressure membrane apparatus)	6.30	6.20	6.20
iii) Bulk density (g/cc) by core method (Dastane 1972)	1.55	1.58	1.65
iv) Available moisture (mm)	16.30	15.75	31.40

Experimental details

The experiment was laid out in a split-plot design, each treatment replicated thrice.

Main-plot treatments — N_0 , N_{50} , N_{100} , N_{150} , N_{200} , N_{250} , N_{300} , kg N/ha
(Nitrogen in the form of Ammonium sulphate)

Sub-plot treatments— Moisture levels-3 : D_1 -25 –ASMD regime, D_2 -50 × ASMD regime,
 D_3 -75 = ASMD regime

Variety-Co 419

The data collected on different attributes were subjected to statistical analysis and tested both at 1% and 5% level of significance. (Fisher 1948). Consumptive use of water, water use per day were calculated according to the formula given by Dastane (1972) and water use efficiency was calculated as per the formula given by Viets (1961).

Results & Discussion

Results

The statistically analysed data on tillers, glucose and sucrose percentages during different crop periods, millable canes, millable cane height, Girth of the cane, cane yield, commercial cane sugar and correlation studies at harvest are presented in Table Nos. 1, 3, 4, 2, 5 and 6 respectively. The trends in rate of dry matter production, nitrogen percentage in 3 to 6 leaf laminae and moisture in 3 to 6 leaf sheaths ; water use efficiency (W. U. E.), rate of water use, Et/Eo ratio are depicted in the Fig. Nos. 2, 3, 4, 5, 6 and 7 respectively.

Discussion

Effect of Nitrogen on cane yield

In the present investigation, higher cane

yields were recorded in the highest nitrogen treatment (300 Kg. N/ha) which was higher by 58.4 percent (Table - 8) as compared to control (0 Kg. N/ha). This is due to substantial increase in growth characteristics viz; number of tillers, number of millable canes, millable cane height and girth of cane (Table 1 and 4 respectively). Nitrogen plays an important role in the synthesis of protoplasm and helps in cell division. At all crop growth stages this treatment recorded higher nitrogen percentage (Fig. 3). Maximum nitrogen percentage was noticed on 95th day of the crop age. The drop in nitrogen percentage in the index issue between the highest (95th day) and lowest recorded periods (harvest) is higher than the other nitrogen treatments. This indicated that nitrogen was better utilized for the production of dry-matter (Fig. 2). Compared to the control the highest nitrogen treatment (300 Kg. N/ha) gave 51% higher water use efficiency. The transpiration ratio was also lowest in this treatment (Table - 8 a) indicating the efficient utilization of water in the production of cane at higher nitrogen levels.

Effect of soil moisture on cane yield

Among different moisture regimes, higher cane yields were recorded in 25 percent ASMD regime. This gave an additional yield of 32 percent as compared to highest depletion treatment (75% ASMD). This is due to substantial increase in dry-matter production to the tune of 52.4 percent (Fig. 2) in 25 per cent ASMD regime as compared to 75 per cent ASDM regime. The higher dry matter production is better utilised for the production of number of millable canes, millable cane height and girth of cane (Table-4). Water is involved in many physiological functions of the plant and physiological activity is higher under lower moisture tensions. As moisture tension decreases, translocation of photosynthates from leaf to stalk increases and consequently the demand for source and sink improves considerably (Humbert 1967). The present results are in conformity with Humbert (1967).

Interaction effect of nitrogen and moisture on cane yield

The nitrogen and moisture have shown additive effect on cane yield. Highest cane yield of 134.6 tonnes/ha (Table-5) was recorded in 300 kg N/ha under 25 percent ASMD regime. At the formative stage of the crop it is very essential to supply the plant with adequate fertilizers and moisture. In the present investigation, cane yield had significant positive correlation with nitrogen percentage (3 to 6 leaf laminae) and moisture percentage in 3-6 leaf sheaths throughout the crop growth period. However, highest significant positive correlation was on 95th day of the crop age. It implies the necessity of

nitrogen and moisture supply during the formative stage of the crop to enable the plant to develop the necessary infrastructure which helps in the subsequent stages of the crop and influences the growth and yield. The highest drop of nitrogen percentage (Fig. 3) in 3 to 6 leaf laminae in 300 kg N/ha under 25% ASMD was observed between 95th day and harvest. This was due to the dilution effect caused by accelerating growth and high dry matter production. Highest significant positive correlation to girth and stalk population was recorded with cane yield (Table-6). Such positive correlations between, cane yield and dry matter and nitrogen and moisture percentages were reported by Lakshimkantham *et al* (1964). Present results are in conformity with their findings.

The best utilization of water in 300 kg N/ha under 25 per cent ASMD regime is evidenced by highest water use efficiency (Fig. 5), consumptive use of water (Table-7) and evapotranspiration ratio (Table-8a).

Effect of Nitrogen and soil moisture on CCS yields

Highest CCS yields of 16.25 tonnes/ha was estimated in 300 kg N/ha under 25% ASMD regime (Table-5). If only nitrogen effect on CCS yields is considered, highest CCS yield was recorded in 200 kg N/ha. Beyond 200 kg N/ha, the sucrose per cent was adversely affected. The CCS yields were decreased as the moisture stress increased. The abundant water is essential for the formation of sugars in the leaves and their translocation to the stalk. Photosynthesis continued at a reduced rate in plants experiencing higher soil moisture stress. Although, less sugar was produced,

more sucrose was accumulated in the stalk by virtue of lowered utilization requirements. This was the reason for higher sucrose percentage in the lower nitrogen doses and higher moisture depletion treatments. The increased sucrose was not considered to be of economic importance because of decreased extractability, and presumably because of reduced tonnage owing to growth restriction (Hart, 1967). The balance between glucose and sucrose per cent in juice is achieved by irrigating the crop frequently at higher nitrogen treatments. Due to favourable rise in sucrose per cent in 300 kg N/ha and 25 per cent ASMD regime combination, highest CCS yields were recorded as compared to other treatment combinations. Lakshmikantham (1973), also reported that increased levels of nitrogen fertilizer have to be associated with increased frequencies of irrigation. Even at the same level of nitrogen more frequent irrigations will lead to high cane and sugar yields. The present results are in full agreement with the findings of Lakshmikantham. The highest nitrogen treatment (300 kg N/ha) coupled with lowest soil moisture depletion regime (25% ASMD) also showed its effectiveness in utilising the

soil moisture effectively for production of CCS yields (Fig. 5, Table 8b).

The CCS yields had high positive significant correlation with dry matter production, plant height, girth of cane and stalk population (Table-10). There was also highest significant positive correlation between CCS yields, sheath moisture and leaf nitrogen percentages on 95th day (Table-10) of crop indicating their highest importance to maintain their percentages on 95th day to get higher CCS yields. This clearly suggests that the application of nitrogen fertilizer (top dressing) should be completed before 95th day of the crop age for 12 months crop.

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* Originals not consulted.

TABLE I

Number of Total Tillers/ M^2 at Different Growth Periods of Crop
as Influenced by Different Treatments

Treatments	Age of the crop								
	67th day	97th day	127th day	157th day	190th day	220th day	250th day	280th day	340th day
(a) Effect of nitrogen									
N ₀	11.56	16.67	14.78	13.44	12.78	11.11	10.67	9.44	9.44
N ₅₀	15.33	19.67	16.56	14.22	13.67	12.44	11.44	10.33	10.22
N ₁₀₀	15.89	19.44	16.89	14.61	14.22	13.22	12.33	10.67	10.66
N ₁₅₀	16.33	20.56	18.22	15.44	15.33	13.78	12.56	11.00	11.11
N ₂₀₀	17.33	21.67	18.56	17.00	16.11	14.11	12.67	11.33	11.22
N ₂₅₀	19.33	21.56	18.89	16.89	15.78	14.11	12.78	11.22	11.22
N ₃₀₀	21.11	21.89	19.22	17.33	16.44	15.00	13.33	12.00	11.44
C. D. 0.05	3.25	2.00	1.70	1.11	1.50	0.95	0.98	1.00	0.66

(Contd.)

(b) Effect of soil moisture regimes :

D ₁	18.95	22.48	18.33	17.71	16.62	15.00	13.62	12.14	11.95
D ₂	16.76	19.95	17.38	15.24	14.90	13.25	11.95	10.67	10.86
D ₃	14.38	18.19	17.05	13.76	13.19	11.90	11.19	9.76	9.48
C. D. 0.05	1.31	1.49	1.48	0.96	0.76	0.49	0.68	0.53	0.49

25 per cent available soil moisture depletion regimes

50 per cent available soil moisture depletion regimes

75 per cent available soil moisture depletion regimes.

D₁D₂D₃

TABLE II

Millable canes (Cooo/ha), Mean Height of Millable Cane (cm) and Girth of cane (cm) at Harvest as Influenced by Different Treatment

Treat- ments	Millable Canes			Mean Height of Millable Cane			Girth of Cane					
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
N ₀	66.0	64.7	60.7	63.8	210.6	194.2	179.9	194.9	9.6	8.5	8.0	8.7
N ₅₀	77.3	70.3	67.3	71.7	237.2	225.9	211.0	224.8	9.8	9.1	8.9	9.3
N ₁₀₀	82.7	75.0	73.0	76.9	254.7	232.0	211.1	234.3	10.0	9.2	8.9	9.4
N ₁₅₀	87.0	78.3	74.7	80.0	264.7	238.5	220.6	241.3	10.3	9.3	9.0	9.5
N ₂₀₀	92.3	79.7	77.3	83.1	273.5	245.0	231.1	249.9	10.6	9.6	8.9	9.7
N ₂₅₀	95.0	82.7	78.7	85.4	281.0	243.6	233.9	252.8	10.7	9.8	9.1	9.9
N ₃₀₀	97.3	85.3	79.3	87.3	289.7	250.4	239.98	260.0	11.0	10.0	9.5	10.2
Mean	85.4	76.6	73.0		259.2	232.8	218.3		10.3	9.4	8.9	

(Contd.)

Nitrogen & Moisture Regime in Sugarcane

Analysis of variance							
SOURCE	'F' Test	S.E.m $\pm$	CD 0.05	'F' Test	S.E.m $\pm$	CD 0.05	'F' est
Nitrogen							
	Sig**	0.89	2.77	Sig**	1.01	0.09	Sig**
Moisture							
	Sig**	3.50	9.93	Sig*	0.35	1.00*	Sig**
Nitrogen X Moisture							
	Sig**	(a) 9.27	26.85	Sig**	(a) 0.93	2.66	N. Sig**
		(b) 8.42	15.03		(b) 0.91	2.49	(a) 0.53 (b) 0.31

CD 0.05

0.15

0.57

—

(a) The difference between the same nitrogen level at different moisture regimes.

(b) The difference between the same moisture regime at different nitrogen levels.

D₁ 25 per cent available soil moisture depletion regime;D₂ 50 percent available soil moistured epletion regime.D₃ 75 per cent available soil moisture depletion regime.

Table-III

Juice Sucrose per cent at Different Growth Periods of the Crop as Influenced
by Different Treatments

Treatments	Age of the Crop											
	At 280th day				At 310th day				At 340th day			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
N ₀	15.0	15.8	16.6	15.8	18.5	18.9	19.9	19.1	18.8	19.8	20.7	19.8
N ₅₀	14.2	15.5	16.5	15.4	18.0	19.2	19.7	18.9	18.8	19.7	20.6	19.7
N ₁₀₀	13.9	14.5	16.0	14.8	16.9	18.7	19.7	18.5	18.7	19.6	20.0	19.4
N ₁₅₀	13.4	14.0	15.1	14.1	16.6	18.1	19.2	17.9	18.2	19.0	19.4	18.9
N ₂₀₀	13.2	14.1	14.6	13.9	16.3	17.4	13.9	17.2	17.6	18.3	18.7	18.2
N ₂₅₀	12.8	12.8	12.6	12.7	15.4	15.5	15.1	15.3	16.9	17.5	16.8	17.1
N ₃₀₀	12.8	12.4	12.0	12.4	14.8	14.9	14.5	14.7	16.8	16.6	15.8	16.4
Mean	13.6	14.1	14.8		16.6	17.5	18.0		18.0	18.6	18.9	

(Contd.)

Nitrogen and Moisture Regime in Sugarcane

Analysis of variance

Source	'F' Test	S.E.m $\pm$	C.D. 0.05	'F' Test	S.E.m $\pm$	C.D. 0.05	'F' Test	S.E.m $\pm$	C.D. 0.05
Nitrogen	Sig. **	0.10	0.34	Sig. **	0.16	0.14	Sig. **	0.06	0.20
Moisture	Sig. **	0.06	0.17	Sig. **	0.07	0.22	Sig. **	0.09	0.28
Nitrogen X Moisture	Sig. **	(a) 0.14 (b) 0.14	0.47 0.32	Sig. **	(a) 0.22 (b) 0.21	0.66 0.59	Sig. **	(a) 0.24 (b) 0.15	0.72 0.41

(a) For the difference between any two moisture regimes at the same level of nitrogen

(b) For the differences between any two nitrogen levels at the same moisture regime

** Significant at 1 per cent level.

Table IV
Juice Glucose Per cent at Different Growth Periods of the Crop as
Influenced by Different Treatments :

Treatment	Age of the Crop.									
	At 280th day				At 310th day				At 340th day	
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean	D ₁	D ₂
N ₀	0.76	0.72	0.58	0.68	0.55	0.52	0.38	0.48	0.32	0.18
N ₅₀	0.85	0.75	0.61	0.73	0.64	0.54	0.46	0.54	0.33	0.21
N ₁₀₀	0.88	0.78	0.65	0.77	0.68	0.63	0.53	0.61	0.40	0.35
N ₁₅₀	0.95	0.85	0.71	0.84	0.81	0.73	0.61	0.71	0.49	0.39
N ₂₀₀	0.03	0.38	0.84	0.92	0.92	0.79	0.72	0.81	0.60	0.48
N ₂₅₀	1.18	1.07	1.18	1.14	0.97	0.87	0.94	0.93	0.68	0.64
N ₃₀₀	1.23	1.24	1.23	1.25	1.06	0.95	1.05	1.02	0.75	0.76
Mean	0.98	0.90	0.84		0.84	0.72	0.67		0.51	0.42

(Contd.)

Analysis of variance

Source	'F' Test	S.Em $\pm$	C.D. 0.05	'F' Test	S.Em $\pm$	C.D. 0.05	'F' Test	S.Em $\pm$	C.D. 0.05
Nitrogen	Sig.**	0.07	0.25	Sig.**	0.03	0.09	Sig.**	0.09	0.03
Moisture	Sig.**	0.04	0.11	Sig.**	0.004	0.01	Sig.**	0.003	0.01
Nitrogen X Moisture	N.Sig.	(a) 0.01 (b) 0.09		Sig.**	(a) 0.01 (b) 0.02	0.03 0.07	Sig.**	(a) 0.009 (b) 0.011	0.03 0.03

(a) For the differences between any two moisture regimes at the same level of nitrogen

(b) For the differences between any two nitrogen levels at the same moisture regime.

** Significant at 1 percent level NS Not Significant.

Table V

**Millable Cane Yield (Tonnes/ha) and Commercial cane Sugar (Tonnes/ha)
As Influenced by Different Treatments**

Treatments	Millable Cane Yield				Commercial Cane Sugar			
	D ₁	D ₂	D ₃	Mean	D ₁	D ₂	D ₃	Mean
N ₀	72.1	70.6	66.4	70.0	9.87	10.17	9.80	9.94
N ₅₀	92.6	83.7	73.5	83.2	11.34	11.50	11.03	11.29
N ₁₀₀	102.2	87.8	78.5	89.8	12.56	12.14	11.48	12.05
N ₁₅₀	110.0	95.4	84.9	96.8	13.58	12.65	11.49	12.58
N ₂₀₀	118.7	98.7	87.5	100.6	14.50	13.04	11.37	12.97
N ₂₅₀	127.1	103.3	90.6	107.0	15.40	13.00	10.50	12.96
N ₃₀₀	134.6	106.0	91.6	110.9	16.25	12.83	9.94	12.82
Mean	108.3	92.2	81.9		13.36	12.19	10.82	

(Contd.)

Analysis of variance

Source	'F' Test	S.E.m. $\pm$	C.D. 0.05	'F' Test	S.E.m. $\pm$	C.D. 0.05
Nitrogen	Sig.**	1.57	5.38	Sig.**	0.21	0.72
Moisture	Sig.**	1.19	3.40	Sig.**	0.13	0.39
Nitrogen X Moisture	Sig.**	(a) 2.75 (b) 2.40	9.01 6.47	Sig.**	(a) 0.34 (b) 0.29	1.03 0.80

(a) The difference between the same nitrogen level at different moisture regimes.

(b) The difference between the same moisture regime at different nitrogen levels

D₁ 25 per cent available soil moisture depletion

D₂ 50 per cent available soil moisture depletion.

D₃ 75 per cent available soil moisture depletion.

Table-6
Correlation Coefficient Values

Character	CROP AGE IN DAYS							
	65th	95th	125th	155th	220th	250th	270th	310th 340th
Simple correlation between								
I Cane yield and								
(a) Leaf nitrogen	0.844*	0.889*	0.835*	0.780*	0.697*	0.636*	0.626*	0.466 0.689*
(b) Sheath moisture	0.726*	0.851*	0.683*	0.816*	0.647*	0.740*	0.150*	0.826* 0.816*
(c) Sheath phosphorus	-0.859*	-0.840*	-0.830*	-0.834*	-0.798*	-0.700*	-0.725*	-0.656* -0.644*
(d) Sheath potassium	-0.499†	-0.390	-0.505†	-0.575*	-0.676*	-0.702*	-0.660*	-0.555* -0.526†
II CCS yield and								
(a) Leaf nitrogen	0.735*	0.788*	0.701*	0.675*	0.365	0.636*	0.501†	0.449 0.307
(b) Sheath moisture	0.724*	0.857*	0.833*	0.601*	0.833*	0.648*	0.706*	0.680* 0.625*
(c) Sheath phosphorus	-0.753*	-0.711*	-0.723*	-0.660*	-0.630*	-0.550*	-0.273	-0.360 -0.462
(d) Sheath potassium	-0.373	-0.312	-0.185	-0.323	-0.437	-0.477	-0.452	-0.345 -0.273
III Growth characters at harvest								
Millable cane height								
(a) Cane yield and	0.974				Millable canes		Girth of cane	Five cane weight
(b) CCS yield and	0.866				0.897		0.927	0.954
					0.845		0.765	0.857

* Significant at 1 percent level

† Significant at 5 percent level.

Table - 7

Seasonal Consumptive use of Water (cm) as Influenced by Various Treatment

Treatment	Available Soil Moisture Depletion			Mean
	25%	50%	75%	
N 0	135.33	126.0	107.2	122.8
N 100	137.3	127.1	107.4	123.9
N 200	138.9	127.6	108.4	125.0
N 300	141.0	129.6	111.3	127.3
Mean	138.1	127.6	108.3	

Table - 8 (a)**Evapotranspiration Ratio As Influenced by Different Treatments**

Treatment	Available Soil Moisture Depletion			Mean
	25%	50%	75%	
N	185.6	178.5	161.4	175.2
0				
N	134.4	144.8	136.8	143.8
100				
N	104.1	117.5	121.0	115.2
200				
N	104.2	117.5	121.0	115.2
300				
Mean	135.3	142.5	135.7	

Table - 8 (b)**Effect of Evapotranspiration on CCS Yield As Influenced by Different Treatments**

Treatment	Available Soil Moisture Depletion			Mean
	25%	50%	75%	
N	1380.8	1238.7	1085.6	1235.1
0				
N	1093.2	1047.0	957.4	1032.5
100				
N	957.9	978.3	960.2	965.5
200				
N	867.6	1021.5	1119.2	1003.8
300				
Mean	1074.9	1071.4	1030.6	1003.8

FIG. 4 MOISTURE PERCENTAGE IN LEAF SHEATH (3-6) AS INFLUENCED BY DIFFERENT TREATMENTS.

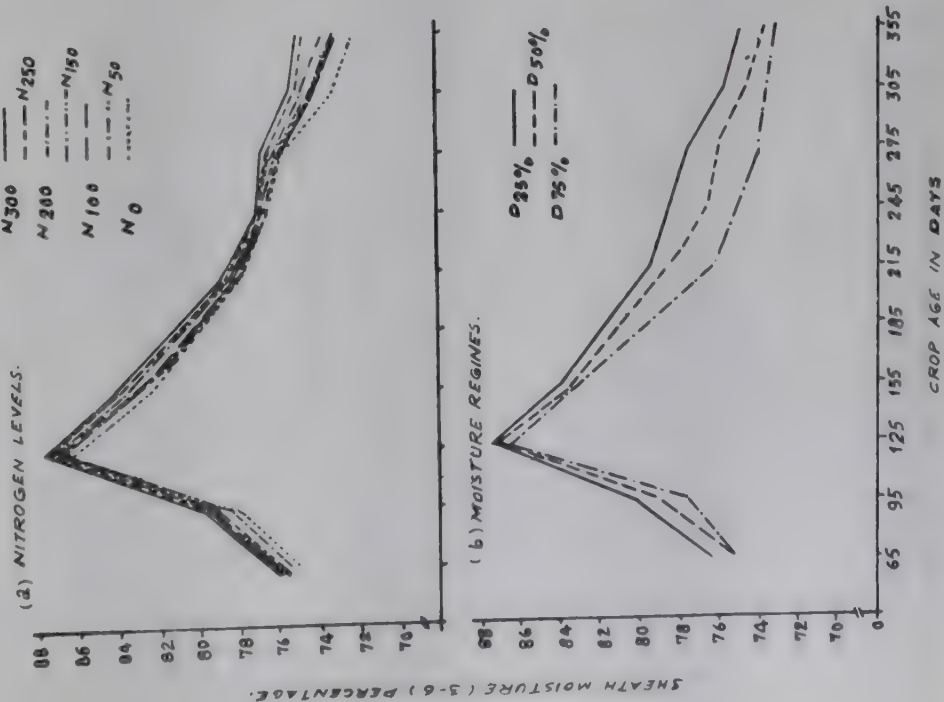


FIG. 1 METEROLOGICAL DATA

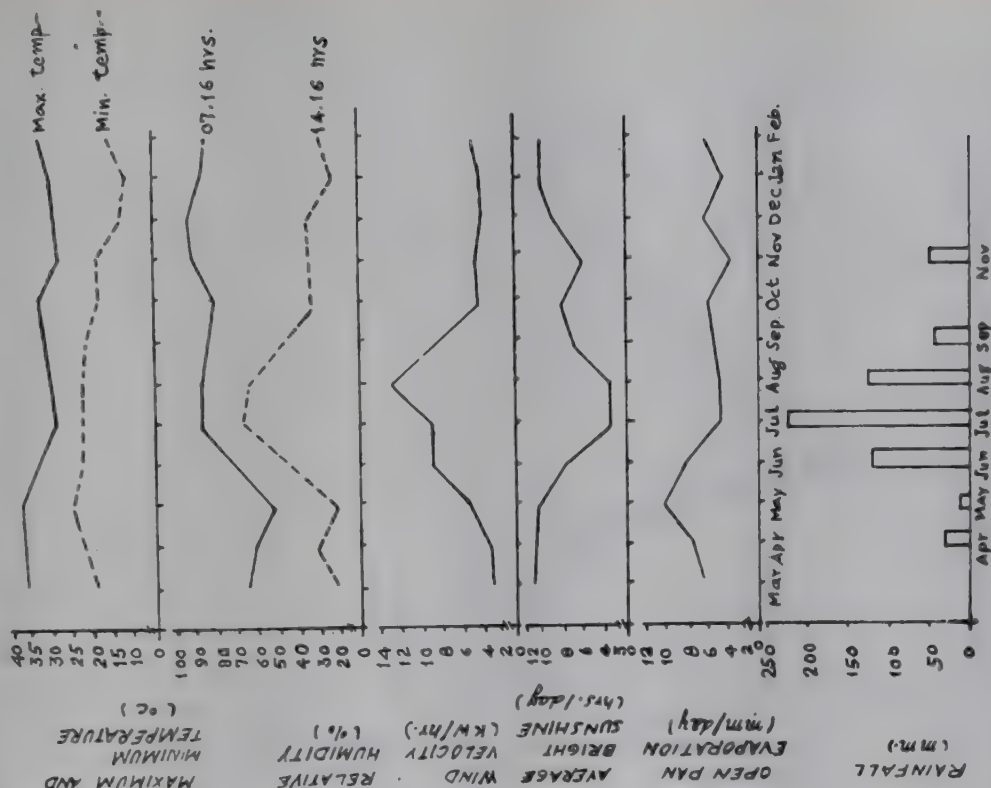


FIG. 2 RATE OF DRY MATTER PRODUCTION (g/day/m^2) AS INFLUENCED BY DIFFERENT TREATMENTS.

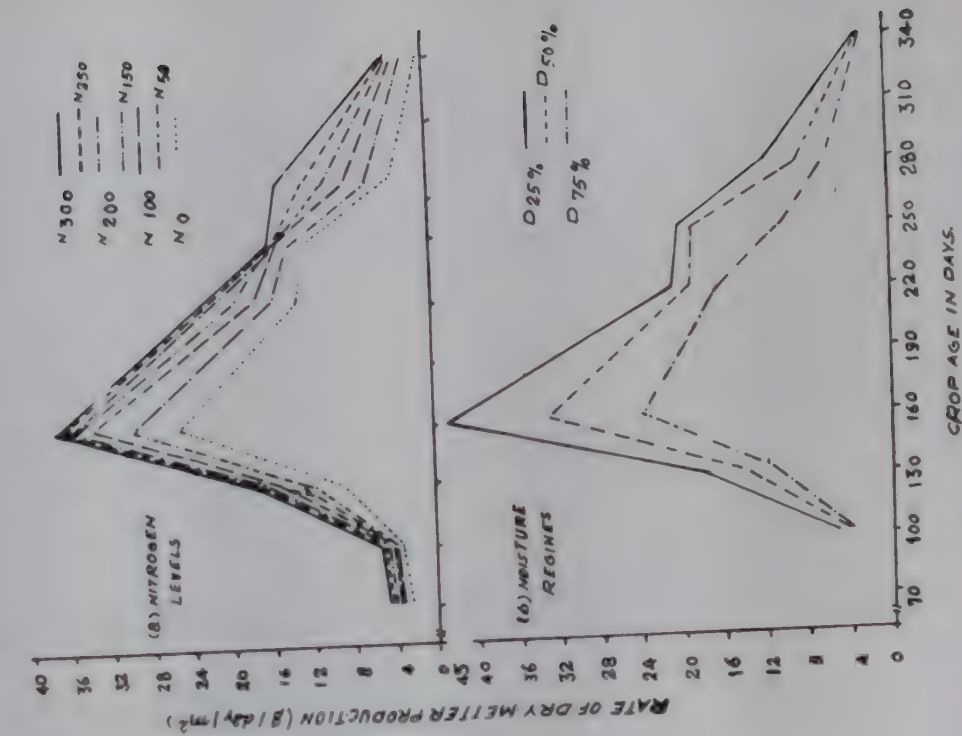


FIG. 3 NITROGEN PERCENTAGE IN LEAF LAMINAE (3-6) AS INFLUENCED BY DIFFERENT TREATMENTS.

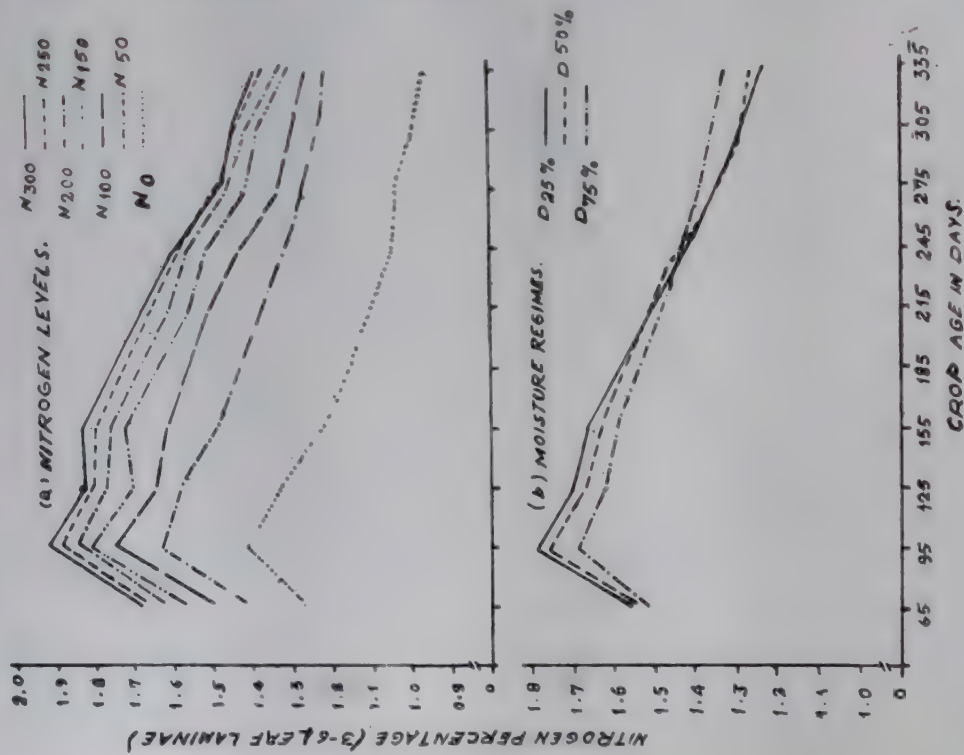


FIG. 5 WATER USE EFFICIENCY FOR CANE AND CCS YIELDS AS INFLUENCED BY DIFFERENT MOISTURE LEVELS AND CROP GROWTH STAGES. FIG. 6 RATE OF WATER USE (mm/day) AS INFLUENCED BY DIFFERENT MOISTURE LEVELS AND CROP GROWTH STAGES.

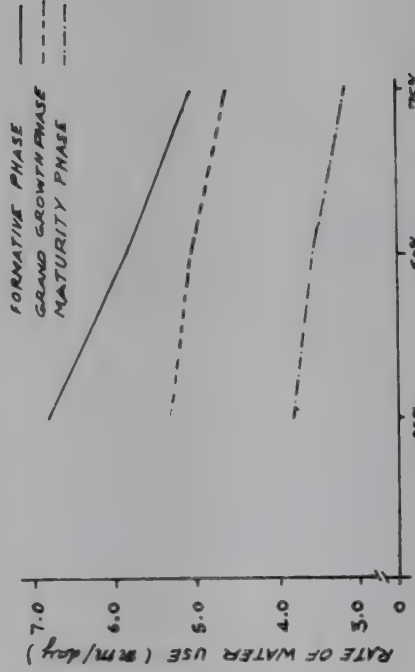
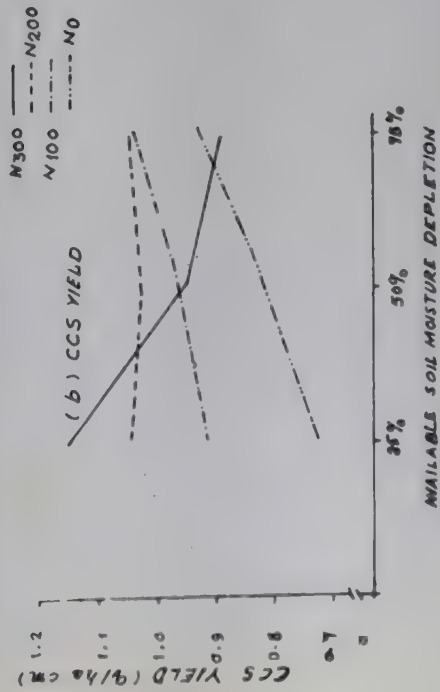
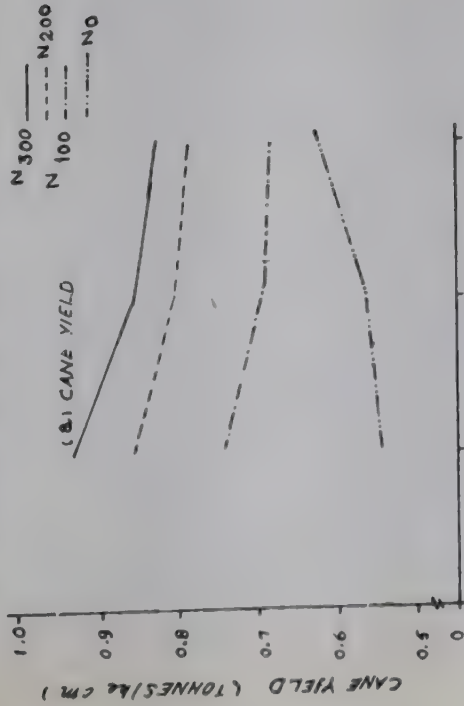
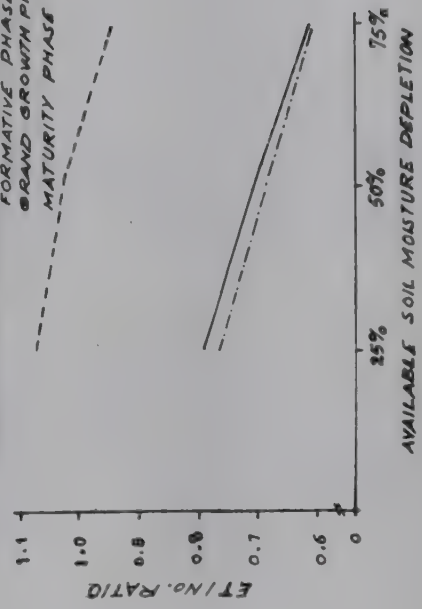


FIG. 7 ET/NO. RATIO AS INFLUENCED BY DIFFERENT MOISTURE LEVELS AND CROP GROWTH STAGES.



STUDIES ON THE SOIL MOISTURE REGIMES IN SUGARCANE UNDER SHALLOW WATER TABLE CONDITIONS OF NORTH INDIA*

By

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ABSTRACT

The results of field experiments conducted at Pantnagar, for three crop seasons viz. 1969-70, 1972-73 and 1973-74 indicated that under shallow water table conditions (< 2 m), irrigating the sugarcane crop at 60% depletion of available soil moisture was inadequate and below 35% resulted in the reduction of cane yield. Irrigating cane at 40% depletion of available soil moisture increased cane yield by 15.2% over 'no irrigation' treatment. To maintain this regime throughout the growing season, the crop had to be irrigated 9 times with a total of 71.6 cm depth of water which was economical bearing in mind the cost of irrigation and the price of cane. The quality of cane was not altered by irrigation treatments.

Introduction :

In India, sugarcane is a crop of 12 to 18 months duration. February planted crop under north Indian conditions matures in 12 months and July planted crop (Adsali) in the state of Maharashtra is harvested at 18 months. The crop responds to the application of irrigation water under both the conditions. The workers of the early sixty's (Singh *et al.*

1960; Rao and Prasad, 1962; Bhoj, 1962 and Verma, 1965) while working of frequency and quantity of irrigation water reported that sugarcane in north India responded upto 125 to 150 cm of water applied in 6-8 irrigations. Whereas under the tropical climate of the south the irrigation need was 225-250 cm of water applied in 30-33 irrigations. Cheema and Moolani (1968), Singh (1969) and Narasinha Rao (1969) who worked on the basis of

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available soil moisture reported that under deep water table conditions (>5 m) 25-50% depletion of available soil moisture in first 30 cm layer of the soil was the best indicator to apply irrigation water in sugarcane. Under conditions of sandy to lomy soil 25% depletion worked better and in loamy to clayee soil 50% depletion proved optimum. However, under shallow water table conditions (<2 m), experiments have not been conducted perhaps with the assumption that the ground water will meet the water need of sugarcane. This assumption may not be true specially when evapotranspiration (ET) demand in the early growth stage, because of high temperature, becomes high. The shallow root system in the early stage of plant growth may not be able to absorb water for its need from ground water. Efforts have, therefore, been made to work out suitable soil moisture regimes under the conditions of a shallow water table where sugarcane is grown very extensively.

Materials and Methods

A field experiment was conducted at the Crop Research, Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, India during 1969-70, 1972-73 and 1973-74. Pantnagar is situated at 29°E and at an altitude of 244 m. Data recorded from the Meteorological observatory, Pantnagar indicate that, in general, the climate of Pantnagar is sub-tropical and humid, receives 1250 mm rainfall in monsoon season (June-September). Wind storms are common in June and September. Winters are cool, frost often occurs from the last week of December to the first week of January. Summers are hot, May and June being the hottest months of the

year. The soil of the experimental plot was silty loam containing 1.2% organic carbon, 55 kg available P and 375 kg available K in the furrow slice of a hectare. The pH of the soil was 7.5 in 1:2.5 soil water suspension. The water table fluctuated from 55 cm in the monsoon season to 163 cm in summer. The values of field capacity (FC) and permanent wilting point (PWP) are given in Table 1.

The experiment consisting of four irrigation treatments (I_0 - no irrigation, excluding the initial irrigation given to start the experiment; I_1 - irrigation at 60% depletion of available soil moisture; I_2 irrigation at 40% depletion and I_3 irrigation at 20% depletion) and five levels of nitrogen, was conducted in a split plot design allotting irrigation treatments to main plots and nitrogen levels to sub plots with four replications each years. The moisture depletion was recorded from all the four layers i. e. 0-15, 15-30, 30-45 and 45-60 cm separately and pooled up for irrigation purposes. Sugarcane variety Co 1158 was planted in the second fortnight of February during each of the three years with a seed rate of 35,000 three budded seed pieces per hectare. Half of the nitrogen through urea (46% N) was applied at planting below the seed pieces and rest top dressed 90-100 days after planting. A dose of 80 kg P_2O_5 as single super phosphate (16% P_2O_5) and 50 kg K_2O as muriate of potash (60% K_2O) per hectare was also applied uniformly to all the plots at planting so that these nutrient elements, though present in soil in sufficient quantities, may not become limiting factors for plant growth. All plant protection measures were followed as and when needed.

To effect irrigation treatments, one common irrigation was given to all the plots 35 days after planting when the germination was almost over. After 2 days of irrigation, soil samples were taken from different depths (0-15, 15-30, 30-45 and 45-60 cm) with the help of screw auger. Moisture percentage on over dry-weight basis were worked out. This process continued till the desired moisture percentage for a particular regime was reached. The volume of water required to bring the soil moisture level to field capacity upto a depth of 60 cm was calculated by the formula suggested by Richards (1947). The required volume of water was measured by parshall flume fixed at the head of the experimental plot.

Since the interaction between levels of nitrogen and soil moisture treatments was statistically not significant, data pertaining to soil moisture treatments only are being discussed within the scope of the paper. The record of depth of water along with number of irrigations and total rainfall received during the each crop season is given in Table 2. The mean monthly evaporation from open pan evaporimeter along with rainfall is depicted in Fig. 1. The evaporation demand was highest in May and June with very little rain received. This period of high evaporation demand coincided with the formative stage of the crop.

Results and Discussion

Irrigation at 40% depletion of available soil moisture increased cane yield significantly over no irrigation treatment during 1969-70 (Table 3). The yield recorded from the plot

either of 60 or 20% depletion remained on a par with that of the no irrigation plot. However, differences in cane yields recorded under the treatments of 60, 40 and 20% depletion were statistically not significant. The difference in millable canes was recorded in the treatment where irrigation was given at 40% depletion of available soil moisture. This shows that frequent irrigations were detrimental even to early growth of the crop specially when there were regular light showers and evaporation demand was not very high (Fig. 1). Frequent irrigation might have created anaerobic conditions in the field which could have resulted in poor uptake of plant nutrients from the soil. Singh (1969) had also reported poor crop growth and yield of sugarcane when irrigated frequently (14 irrigations).

During 1972-73, the highest cane yield was received from plots irrigated at 20% depletion of soil moisture followed by the plot where irrigation was given at 40% depletion. Both these treatments at about the same yield level gave a significantly higher cane yield than the treatments of no irrigation and 60% depletion. The yield levels of the treatment of no irrigation and that of 60% depletion were the same. As compared to the previous year the pan evaporation was much higher during 1972-73 and rainfall was also relatively low. This must have created water stress conditions in the plots irrigated less frequently and the high evapotranspiration (ET) demand of the plant could not meet by less frequent irrigations than 20% depletion of available soil moisture. Like number of shoots, millable canes were significantly higher in the treatment of 20% depletion of available soil

moisture as compared to the treatments of no irrigation and 60% depletion. The difference in yield was primarily because of difference in number of shoots and millable canes. On an average the treatment of 20% depletion increased shoot number by 34% over that of 60% depletion. But the yield did not increase in the same proportion as was the case with shoot number as the difference in millable canes narrowed down to 16% only. This was because of higher mortality of shoots in case of more thickly populated plots. The mortality in case of the treatment of 20% depletion was 55% and 43% in case of 60% depletion. Kanwar and Sharma (1974) found tiller mortality of 57, 37.5, 34.1, 26.1 and 18.9% in a row spacing of 60, 90, 120, 150 and 180 cm, respectively. This phenomenon could be ascribed to the inadequacy of light in the lower horizon under dense canopy created by higher plant population. In the absence of optimum light the weaker tillers are likely to die because of inability to compete with more vigorous stalks.

In the 1973-74 season, though the differences in cane yields under different treatments were statistically not significant, the treatment of 40% depletion of soil moisture produced highest cane yield which was 10 tonnes higher than the yield recorded under control (no irrigation). The differences in other plant characters like the number of shoots and millable canes were also not significant (Table 3). The probable reason for lack of response to irrigation could be attributed to frequent rainfall received during the early period of crop growth (Fig. 1), reflected by the uniform tiller formation irrespective of the treatments. The tiller mortality also remained similar in

all the treatments as the initial population was the same. Hence the cane yield under different treatments remained unaffected.

The quality of juice was not affected by irrigation treatments over the three years of the investigations. (Table 4).

Average data over the whole period indicated that the absolute yield increase over no irrigation treatment was 3.4, 12.1 and 8.7 t/ha in the treatments of 60, 40 and 20% depletion of available soil moisture, respectively with corresponding per cent increase of 4.3, 15.2 and 10.9. The average number of irrigations given were 3, 9 and 19 with 45.7, 71.6 and 98.9 cm water. The cane yield found to be associated with the number of millable canes. A coefficient of correlation of 0.9 between cane yield and millable cane number has been reported by Raghuvaiya (1974). The average cane yield data were very well fitted into the quadratic function of orthogonality. The regression equation so fitted indicated (Fig. 2) that the cane yield went on increasing upto 20% depletion of available moisture beyond which there was sharp decline in yield. The optimum moisture depletion was 35%. This clearly indicated that irrigating the crop at 60% depletion of available soil moisture was inadequate and below 35% the yield showed a declining trend and reached to detrimental level below 20 percent depletion.

Acknowledgement

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Table 1
Physical Attributes of Experimental Soil

Soil depth cm	Bulk density* g/cm ³	Field capacity** (% moisture)	Permanent wilting point (% water)+	Available water (cm)
0 15	1.69	22.3	6.1	5.1
15—30	1.64	22.6	7.1	3.8
30 -45	1.60	22.3	7.2	3.6
45—60	1.69	22.3	8.6	3.5

* Core method (Blake, 1965)

**Field method (Peters, 1965)

+ Pressure membrane apparatus (Richards, 1947)

Table—2
Amount of Water Applied and Total Rainfall Received During the
Course of Investigation

Treatment	Number of irrigations		Amount of water applied (cm)	Rainfall (mm)
	Pre-monsoon /	Post-monsoon		
1969—70				
1. No irrigation	1	—	8.0	1351
2. Irrigation at 60% DASM	2	1	45.2	1351
3. Irrigation at 40% DASM	7	2	70.5	1351
4. Irrigation at 20% DASM	13	6	98.8	1351
1972 - 73				
1. No irrigation	1	—	8.0	1254
2. Irrigation at 60% DASM	3	1	52.2	1254
3. Irrigation at 40% DASM	8	3	77.4	1254
4. Irrigation at 20% DASM	14	7	115.8	1254
1973—74				
1. No irrigation	1	—	8.0	2066
2. Irrigation at 60% DASM	2	1	39.8	2066
3. Irrigation at 40% DASM	5	2	67.1	2066
4. Irrigation at 20% DASM	12	5	82.0	2066

DASM—Stands for depletion of available soil moisture throughout the paper

Table-3

Effect of Soil Moisture Regimes on the Number of Tillers, Milable Canes and Cane Yield of Sugarcane Variety Co 1158.

Treatment	1969-70	1972-73	1973-74	Mean
Number of tillers 000/ha				
1. No irrigation	162	175	150	162
2. Irrigation at 60% DASM	149	158	177	161
3. Irrigation at 40% DASM	157	214	178	183
4. Irrigation at 20% DASM	122	235	172	176
S. E.m $\pm$	8	9	9	
CD 5 $\pm$	NS	29.6	NS	
Number of millable canes 000/ha				
1. No irrigation	88.2	97.5	84.0	89.9
2. Irrigation at 60% DASM	90.3	90.0	87.0	89.1
3. Irrigation at 40% DASM	95.9	105.6	88.0	96.5
4. Irrigation at 20% DASM	88.7	104.8	86.0	93.2
S. E.m $\pm$	4.2	3.1	3.0	
5. CD 5%	NS	10.6	NS	
Cane yield/t/ha				
1. No irrigation	74.1	90.6	64.4	79.7
2. Irrigation at 60% DASM	79.1	89.4	80.4	83.1
3. Irrigation at 40% DASM	83.7	106.4	85.2	91.8
4. Irrigation at 20% DASM	79.1	109.0	80.2	89.4
S. E.m $\pm$	2.1	2.5	2.8	
C. D. 5%	5.8	8.7	NS	

Table-4**Effect of Soil Moisture Regimes on the Quality of Juice of Sugarcane Variety Co 1158**

Treatment	1969 - 70 %sucrose in Juice	1972 - 73 Brix	1973-74 % sucrose in juice
1. No irrigation	16.8	20.6	16.0
2. Irrigation at 60% DASM	17.0	20.6	16.5
3. Irrigation at 40% DASM	16.6	20.6	16.2
4. Irrigation at 20% DASM	17.7	20.7	16.1
S. E.m $\pm$	0.3	0.2	0.4
C. D. 5%	NS	NS	NS

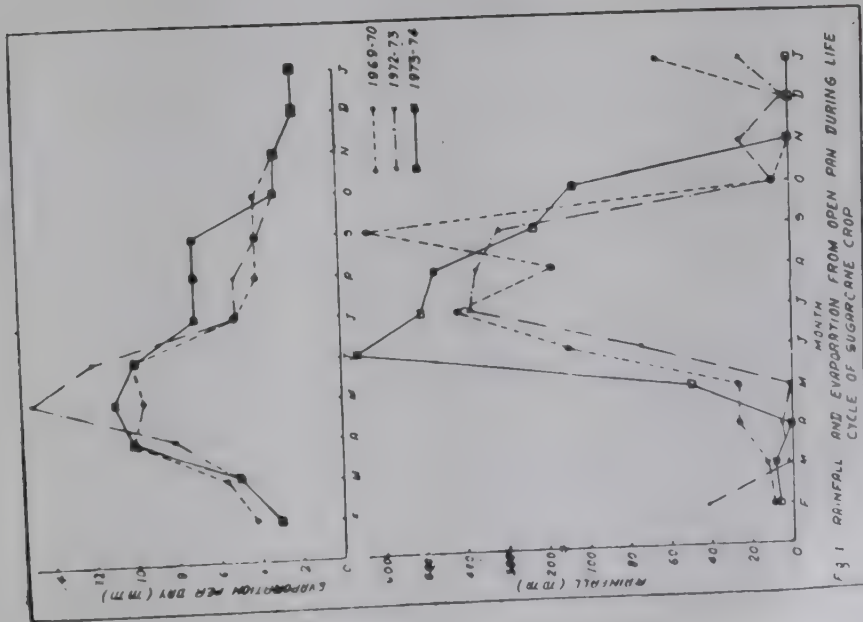


Fig 3. RAINFALL AND EVAPORATION FROM OPEN PAN DURING LIFE CYCLE OF SUGARCANE CROP

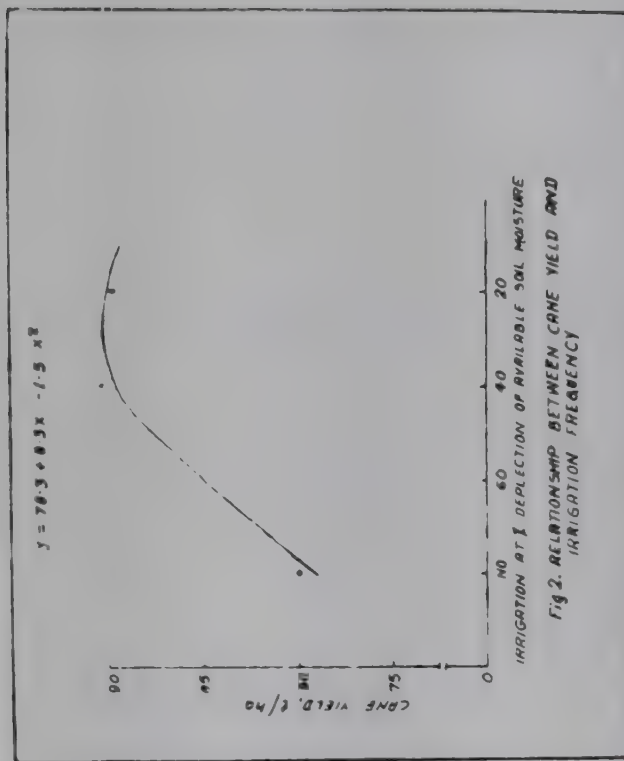


Fig 2. RELATIONSHIP BETWEEN CANE YIELD AND IRRIGATION FREQUENCY

RECENT CANE PRODUCTION TECHNOLOGY

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Introduction

Sugarcane crop is grown in India in two distinct regions viz; the tropical and the sub-tropical. The total area under sugarcane crop is 2.87 million hectares out of which 30 per cent is in the tropical belt and 70 per cent in the sub-tropical region. The area in major cane growing states is given below :

Sub-Tropical region

State	Area lakh hectare
Uttar Pradesh	14.91
Haryana	1.68
Bihar	1.28
Punjab	1.13
Maharashtra	2.41
Andhra Pradesh	1.52

Tropical region

State	Area lakh hectare
Tamil Nadu	1.33
Karnataka	1.23

The average cane yield for the tropical belt is approximately 70 tonnes per hectare and 48 tonnes for the northern sub-tropical region. There is considerable scope for improving the yield level in both the regions if improved cane cultivation techniques are taken up. In northern India it should be possible to raise the level of average yield to 65 tonnes per hectare and 90 tonnes in the tropical cane growing areas.

The highest potential yield of sugarcane is estimated at 474.24 tonnes per hectare. The maximum yield obtained so far for two years crop in Hawaii is 450.95 tonnes per hectare. In India, the highest yield of 440.85 tonnes per hectare for 18 months crop (Adsali) and 406.38 tonnes per hectare from a twelve

months crop was obtained in the cane competition plots in Maharashtra State. In the Northern region, the highest yield obtained in cane competition plots is 335.42 tonnes per hectare. This indicates clearly the tremendous possibilities for increasing cane yield per unit area in the country both in the tropical and sub-tropical regions.

The aim of cane production technology, however, should not be to increase cane yield alone but emphasis should be on production of more sugar per unit area. This calls for more emphasis on crushing the crop at the right time of its maturity and growing of high sugar varieties with good tonnage. The technology had improved considerably during the last one decade, the adoption of which can enhance the cane yield and sugar recovery to a considerably higher level. Some important aspects of the cane production technology developed by various research Institutions and Universities in the country which can be translated into the field are summarised below :

1. Choice of Suitable Cane Varieties

Late maturing high tonnage varieties like Co. 1148 in North India and Co. 740 in Maharashtra continue to occupy major area under sugarcane. There is urgent need of cultivation of early maturing high sugar varieties like Co. 997 Co. 1336, Co. 6806 and Co. J. 64. Out of these, Co. 997 has been badly affected with red rot disease in Andhra Pradesh and has gone out of cultivation. Co. 1336 and Co. 6806 though high in sugar content have not made any headway in North India due to poor yield and other undesirable agronomic characters, Co. J. 64 which was released in

Punjab for cultivation in 1975, has shown very good performance in the state and occupies about, 30,000 acre area in Punjab at present. This variety combines cane yield and sugar content to a considerably high degree and thus meets the requirements of the growers, as well as the millers. The variety is being tested in the states of Uttar Pradesh, Bihar, Haryana, Madhya Pradesh, Gujrat and Tamil Nadu. Experiments conducted with this variety in the Punjab state have clearly brought out that this variety yields more sugar per unit area than Co. 1148—a late maturing high cane tonnage variety. As ultimately it is the sugar produced per unit area that matters, there is urgent need of developing and cultivation of high sugar varieties like Co. J. 64.

Another important recommendation that needs to be implemented is the introduction of varietal crushing schedule based on maturity of different varieties. This schedule has been introduced in some of the factories in the Punjab state and has proved successful. As compared to maturity harvesting, varietal crushing schedule is easy to implement. In Batala Sugar Factory in the Punjab state, Co. J. 64 — an early maturing high sugar variety was crushed in November—December, Co. J. 46 and Co. J. 67 (mid-season) in January—February and Co. 1148 (late) in March—April. By adoption of this schedule the sugar recovery of Batala factory during 1976-77 was 10.18 per cent which is the highest recovery ever achieved in the state. For cultivation of high sugar varieties higher price should be paid by the industry as is being done in Punjab for Co. J. 64 variety.

Cane Culture

1. Planting Techniques

i) Ridge planting

While in North India most of the cane is planted by flat method of planting, in the tropical cane growing region trench planting method is used. However, ridge method of planting needs to be mentioned here. This method of planting is practised in Louisiana and in parts of Puerto Rico, where the water table is high. In this method ridges 45 cm. high are made with a tractor drawn ridger

and a miniature furrow is drawn at the top of the ridge and the seed setts planted. The setts are covered with a thin layer of soil and the field irrigated. This method needs to be tried in areas where water table is high.

ii) IISR 8626 method of planting

This method developed by the Indian Institute of Sugarcane Research involves planting of pre-germinated 45 cm. long top setts vertically in deep trenches which are fully filled, fertilised and irrigated at the time of planting. The details of this method are given below :

Trenches	45 cm. deep, 20 cm. wide and 90 cm. apart.
Digging of trenches	Before planting.
Filling of trenches	Just before planting
Fertilizer application	Nitrogen at 150 Kg. and P_2O_5 100 Kg. per hectare is applied at the time of planting.
Irrigation at planting	Uniformly fertilized and filled up trenches are irrigated just before planting.
Seed material	45 cm long top setts are made to germinate on the canes standing in the field by decapitating ungerminated top setts can also be used for vertical planting.
Planting	Leaves of the shoots developed on the top setts are clipped just before they are cut for planting. These setts are planted vertically so that the bud ends touch the bottom of the trench and the bases of 2 or

Contd.

4 rayagan shoots on the setts are in the soil while their tips are well out of it.

Total number of irrigations	6 to 12 depending upon the time of planting.
Labour for digging trenches.	200 to 350 man days.

This method of planting was tried at the IISR, Lucknow and at the State Sugarcane Research Stations, but due to difficulty of digging deep and narrow trenches it has not found favour with the growers.

iii) *Space transplanting technique*

The technique involves transplanting of pre-germinated shoots either vertically or horizontally.

a) *Vertical transplanting*

A nursery is raised a month ahead of the normal planting time in an area of 5 metre long and 5 metre wide. Single bud setts drawn from the top half portion of the cane stalk are planted vertically in the nursery and covered with dried cane leaves. About 2 tonnes of seed cane (12,000 setts) are required to be raised in the nursery for planting in an area of one hectare. The sprouts are transplanted in the field in rows with 90 cm. spacing. Properly raised transplants that are properly spaced and maintained, possess a much high tillering capacity and can out yield crops raised by conventional method. Since the

spaced plants enjoy better sunlight distribution within the crop canopy, stalk thickness is more and uniform. About 35 per cent increase in yield over the conventional method has been reported.

b) *Horizontal transplanting*

In this technique single bud setts are planted horizontally in the nursery bed with bud position upward. The setts are placed close to each other and are covered with a thin layer of soil. Water is applied with a watering can and the nursery bed covered with polythene sheet. Covering the nursery bed with polythene sheet is essential in low temperature areas during January and February. After completion of germination in the nursery the single bud setts are dug out carefully and transplanted horizontally in the field at 90 cm row to row spacing and 60 cm. plant to plant spacing within row. The comparative cost of cultivation of horizontal transplanting and the conventional method of planting is given below. The horizontal transplanting has shown better result than the vertical transplanting.

Comparative Cost of Transplanting and sett Planting one-acre

Transplanting		Sett planting	
1. Interrow spacing	90 cm.	Interrow spacing	90 cm.
2. Plant to plant spacing	60 cm.	Quantity of seed required to plant one acre	30 qtl.
3. Number of single budded setts required to transplant one acre	7260	Cost of 30 qtls seed at 15/- per qtl.	Rs. 450/-
4. Area a nursery required for planting 7260 single budded setts.	1/160 acre	Cost of preparation of seed and planting	Rs. 175/-
5. Quantity of seed required for raising nursery for planting	5 qtl.		
6. Cost of 5 qtl seed	Rs. 75/-		
7. Cost of making single budded setts and planting in nursery 6 men	Rs. 42/-		
8. Care of nursery till transplant in field - 5 men	Rs. 35/-		
9. Cost of transplanting one acre - 8 men	Rs. 56/-		
Total :			625/-

iv) *Polythene bag transplanting technique*

This technique has been developed at the PAU Sugarcane Research Station, Jullundur and is an improvement over the space transplanting technique. In this technique, single bud cuttings are planted in the top soil layer in one Kg. Soil filled polythene bags with bud position upward. The upper soil surface is kept wet for good germination of buds. There is almost 100 per cent germination. The germinated shoots are then transplanted in the field along with earth ball after cutting the polythene sheet with a blade. The shoots so transplanted establish themselves very quickly compared to the space transplanted technique as with the earth ball there is no disturbance to the root system of the young germinated shoots. This technique is very useful for quick propagation of newly developed cane varieties.

2. **Role of Plasticulture in Sugarcane**

The use of plastics has increased considerably in crop production particularly in countries like Japan, Israel, South Africa, Australia and Hawaii in drip irrigation, mulching and green houses. Studies on drip irrigation need to be taken up in India particularly in the tropical cane growing belt as water needs of the crop are very high under those conditions. With drip irrigation the water use efficiency increases manifold. The use of polythene mulch has also been found to improve sprouting of ratoon crop and germination in low temperature areas.

3. **Improving nutrient efficiency**

Soil application of Gamma BHC at 2 litre per acre as emulsion over the seed sets at the

time of planting has been found to have a boosting effect on the crop growth due to improved efficiency of nitrogen. Recent trials conducted in the states of Maharashtra and Bihar have confirmed these results. It is, therefore, strongly recommended that soil application of Gamma BHC and other suitable pesticides should be taken up on a large scale in India to improve cane yields. Another way of improving the efficiency of nitrogen is drilling of nitrogen in the root zone. At present the second dose of nitrogen to the crop is applied by broadcast in May or June which results in considerable loss of this nutrient. Late application of nitrogen should also be discouraged as the results in loss of nitrogen and also delays the maturity of cane. Recent investigations have, however, shown that the ratoon crop needs phosphorus and potash for obtaining higher yield. Deficiency of some micro-nutrients particularly iron has also been detected in the ratoon crop. In order to overcome this deficiency foliar application of Ferrous Sulphate is recommended.

4. **Autumn Planting**

The research work carried out in North India has conclusively proved that autumn planting of sugarcane gives 25-30 per cent higher yield than spring and also yield 0.5 to 1.0 per cent higher sugar recovery. In view of those results it is strongly recommended that autumn planting of sugarcane should be taken up on a large scale in north India. Intercrops like wheat, potato, raya, toria, senji, turnips, sugarbeet can also be grown successfully in autumn cane, which give additional income to the farmer per unit area.

In the spring crop short duration moong can be successfully intercropped in North India. In view of major emphasis on pulses production by the Government of India, intercropping of spring sugarcane with moong should be taken up on a large scale.

5. Seed Rate, Seed Sett Size and Interrow Spacings

In the tropical region the seed rate varies from 12,000 to 20,000 three budded setts per acre. In North Indian region the seed rate used in Uttar Pradesh varies from 12,000 to 15,000 three budded setts per acre. This seed rate is low and affects the stalk population adversely. By increasing the seed rate to 20,000 setts per acre the stalk population can be increased for obtaining higher cane yield.

In India 3 budded setts are mostly used for planting. Recent investigations at the PAU Sugarcane Research Station, Jullundur have shown that the size of sett can be increased to 5 budded or six budded setts without any detrimental effect on germination and yield of sugarcane. The cost of seed preparation comes down considerably by increasing the size of the seed sett.

In most of the north Indian cane growing states, cane is planted in rows 90 cm apart. In the tropical belt the spacing varies from 90—135 cm. Recent investigations at the PAU Sugarcane Research Station, Jullundur have shown that the interrow spacing in the northern cane growing region can be increased to 120 cm. without any adverse effect of stalk population and yield. These findings have opened the scope of growing intercrops

successfully in sugarcane. In the ratoon crop the yield differences among 60, 80, 120, 150, and 180 cms interrow spacing were non-significant. These results clearly show that interrow spacing can be increased in the northern subtropical region.

6. Chemical Weed Control

Sugarcane crop is infested with a number of broad leaved weeds, annual grasses and *Cyperus rotundus*. The weeds affect the crop growth and yield adversely. It is more economical to control weeds by using chemicals. Pre-emergence application of Diuron at 2 Kg./ha. has been found to be more effective in controlling weeds than Triazine compounds, like Simazine. Diuron has also a longer residual effect than Simazine and also keeps *Cyperus rotundus* under check. One post-emergence application of Grammaxone at 4.51 lit/ha has been found to keep *Cyperus rotundus* under control. In recent experiments at the PAU Sugarcane Research Station, Jullundur pre-emergence application of Sencor at 2 Kg./ha has shown better results than Diuron. This chemical has shown good suppressing effect on *Cyperus rotundus* also.

7. Role of Mulches in Cane Production

Trash mulch recommended in sugarcane to conserve moisture and improve sprouting of ratoon of early harvested crop (November-December). Recent investigations, however, proved that trash mulch should not be used to improve sprouting of ratoon crop harvested during the low temperature period i. e. November and December. In fact covering the harvested stubbles with trash during

November-December adversely affects the sprouting due to its shading effect resulting in low soil temperature during the day. The use of trash also results in the developing of fungus on the cut ends of the stubbles in the depressing sprouting. Soil compaction is another factor due to which the sprouting of early harvested ratoon crop is poor. Recent investigation have shown that the soil compaction should be broken immediately after harvesting the crop by hoeing or interculture. This improve the sprouting of ratoon crop considerably. Some experiments in progress at the PAU Sugarcane Research Station, Jullundur have shown highly beneficial effect of polythene mulch, paddy husk and paddy straw mulches. As paddy husk is available in large quantities it is suggested that mulching with paddy husk should be done to conserve and improve yields in the spring planted crop. The above mentioned have proved more effective than sugarcane trash mulch and wheat straw.

8. Late planting technology

Inspite of emphasis on timely planting of sugarcane; considerable area is still planted late i.e. after harvesting of wheat in end April or May in Northern India. Due to late planting the tillering is adversely affected as a result of which the plant population remains low. The growth period is also shortened resulting in poor crop growth and ultimately low yield. The pests like shoot borer also damage the late planted crop severely. In order to attain good yield from a late planted crop, a higher seed rate of 30,000 three budded setts per acre is recommended to have higher initial plant population. Soil application of

Gamma BHC is also absolutely essential in the late planted crop to save it from the shoot borer damage and boosting growth. Suitable varieties should also be selected for late planting.

9. Use of chemical ripeners

Chemical ripeners are now being used extensively in sugarcane in Hawaii, Brazil, and South Africa. The use of these chemicals is more useful in 'difficult to ripen tropical areas.' Research work carried out in India has shown that pre harvest foliar application of Polaris at 2.15 Kg/ha and Ethrel at 500 ppm induce early maturity in cane giving 2.5 unit higher sucrose content. Experiments conducted at the PAU Sugarcane Research Station, Jullundur have shown that Etarel at 500 ppm is more effective chemical ripener than Polaris. The cost of Ethrel at 500 ppm rate is about Rs. 125/- per acre. It is suggested that the use of chemical ripeners should be taken up in sugarcane particularly in tropical areas.

III. Seed Production Technology

Till recently of the farmers in India have been using seed from the commercial crop except a few states like Andhra Pradesh where a separate seed crop is raised. The use of commercial crop for seed purposes results in poor germination and the spread of pests and diseases. During the last decade, however, attention has been paid to purchase disease free seed. The following measures are recommended for raising a healthy seed crop improving the yield of plant and ratoon crop.

(i) *Heat therapy*

Heat therapy in the form of hot air treatment, hot water treatment and aerated steam treatment is recommended for controlling the two important virus diseases viz. grassy shoot and ratoon stunting. The ratoon stunting disease is widely prevalent in sugarcane crop in India and is responsible for reduction in the yield particularly the ratoon crop. Heat therapy of sugarcane seed should, therefore, be taken up on a large scale to cover the maximum area in the shortest possible time.

(ii) *Short duration seed crop*

Young immature seed crop always gives better germination. In some of the states like Andhra Pradesh short duration crop is being raised and planted. The short duration crop needs to be popularised throughout the tropical cane growing belt for obtaining better germination and plant population. In north India, it is difficult to obtain a short duration crop due to climatic reasons but for autumn planting short duration crop is available.

(iii) *Use of top setts for planting*

Top immature cane setts always give better germination than the bottom buds. It is, therefore, recommended that 2/3rd top portion of cane seed stalk should be used and the bottom 1/3rd portion should be crushed for making 'Gur' or supply to the sugar mills.

(iv) *Use of systemic insecticides for top borer control.*

Top borer is a serious pest of sugarcane and has been responsible for the running out of susceptible varieties. Foliar application of different chemicals did not prove successful in controlling this pest. Recently, however, soil application of systemic insecticides like Carbofuran and Thimet has been found to control this insect effectively. Carbofuran (Furadan 3 G) and Thimet (10 G) are applied in the last week of June or First week of July along the cane rows and irrigation applied immediately afterwards to control the third brood of this pest which is more serious.

Engineering & Chem. Engineering Section

POSSIBILITIES OF REDUCTION IN POWER CONSUMPTION OF INDIAN SUGAR FACTORIES CONDENSING SYSTEM A TYPICAL CASE

By

J. P. Mukherji and S. B. Bhad

ABSTRACT

The conventional standard condensing and cooling system for Indian Sugar plants is having MJS condensers with individual injection water pumps and spray pond. Authors have suggested this system with barometric condensers with individual water jet air extractors and cooling tower. This system will reduce the power consumption to 40% i.e. @ 175 KW instead of 425 KW) and capital cost to 50% (i.e. 7 lakhs instead of 14.5 lakhs) of the conventional system.

The standard 1250 TCD factory has five MJS condensers, each with its individual 700 m³/hr. pumps delivering water at a total head of 25 m. For spraying water in the spray-pond there are two 1600 m³/hr. pumps delivering water at 10 m total head. The usual operating conditions in March and April in India are, in 1st water temp. to condenser — 34/36°C and outlet water temp. 39/42°C; a temp. rise of only 5/6°C. The connected load of all these pumps is approx. 680 B. H. P. which at the alternator end is approx. 600 K.W. The demand of electrical power is approx. 425 K.W. on this account. Our aim is to find ways and means of reducing this power consumption.

Condenser is a direct contact heat exchanger. If we can increase the temperature range of heating the injection water, the water needed to condense same quantity of vapours will proportionately go down i.e. if the injection water is at a temperature of 30°C and condenser outlet water is at a temperature of 50°C, the temp. rise being 20°C, water requirements will go down to 1/4th of water is now being pumped to the condenser. This would mean a reduction in power consumption to 1/4th of what is being required now. However, as it will be shown, the power consumption in the cooling system i.e. the spray pond or in cooling tower will not go down proportionately and there will be additional power requirement

for extraction of air and non-condensable gases with vacuum pump or by an water jet air extractor.

The conventional spray cooling pond performance is very poor, the cooling range rarely exceeds $5/6^{\circ}\text{C}$ whereas we need to cool 20°C . For this purpose we need a cooling tower or multiple spray cooling. The power consumption of the tower will be approx. 85 K.W. for cooling $900 \text{ m}^3/\text{hr.}$ water that will be needed for a 1250 TCD factory.

For air and non-condensable gas extraction the ideal is to use individual water ring vacuum pumps. However, these pumps are not only relatively costly but also the power consumption of vacuum pumps available in India is high. Therefore, in most of the cases water jet ejector (power consumption compared with properly manufactured water ring vacuum pump 1.54 times) is attractive. In a multi-jet spray condenser almost 50% and in some cases more power is consumed by the jets, though this should not be more than 40%. When we locate the air extractor section of a MJS condenser outside, the outlet water from the extractor can be re-used for the condenser without further cooling as there is no significant rise in temperature. Assuming the same water is used for condenser after air extraction, the circulating water being one-fourth in quantity, the air to be extracted due to injection water will go down; proportionately. There will be further reduction in the volume of air if the MJS condenser is changed to a barometric counter current type due to lowered outlet gas temp. If the MJS body is retained the outlet gas temp. will rise and the water

requirement at the jet extractor will go up, though not significantly. The water and hence power requirement of the extractor may be taken as same as that of the condenser, to be on the safe side, till experience teaches us that this could be less.

So far we have talked of reduction in the water requirement and proportional power reduction. Most of our MJS condensers work with pumps operating at a head of approx. 25 metres. If the MJS condensers being supplied were properly designed and manufactured and the system design had taken all aspect into consideration the working head of pumps could have been 18 metres only. When MJS condensers are converted into multi-spray condensers or replaced with efficient barometric counter current condenser (i.e. terminal difference, $t_1 - t_2$ approx. 3°C), the operating head can go down to 12 metres and corresponding reduction in power.

Summarising the power consumption in the condenser section of a condensing system of a 1250 TCD sugar factory can go down to $(.25 + .25) \times .5 = 0.25$ of the power being used now, if the inlet water to the condenser is available at 30°C and condenser can heat this water to 50°C . Hence power requirement of this section will go down to 85 K.W. If we add to this, power consumption of the cooling tower which will be 85 K.W. the total power consumption of the condensing system will come down to 170/175 K.W. instead of the present figure of approx. 400/425 K.W.; a saving of 230/235 K.W. i.e. the power consumption will come down to 40/45% of the present figure of 400/425 K.W. The capital

expenses will also come down to 7 lakhs from the present figure of 14.5 lakhs. (Please refer annexure-I).

seminar and solutions to individual cases resulting in significant power saving, reduction in capital expenses and improvements in vacuum performance will result.

Writers hope that above typical example will trigger thoughts on the subject in this

Annexure - I

I. Cost of conventional condensing and cooling system (i.e. MJS condensers with individual injection water pumps and spray pond.) for 1250 TCD plant :-

i. MJS condensers — 5 nos.	Rs. 1,30,000/-
ii. Injection water pumpset. — 5 Nos. (700 M ³ /hr. capacity and 25 M head each)	Rs. 2,00,000/-
iii. Spray pond pumpsets — 2 nos. (1600 M ³ /hr. capacity & 10 M head each)	Rs. 1,40,000/-
iv. Spray pond C. I. piping and nozzles	Rs. 2,00,000/-
v. Spray pond basis (3250 M ² area)	Rs. 4,00,000/-
vi. Hot and cold water channels (Suitable for 3200 M ³ /hr)	Rs. 70,000/-
vii. Additional cost of 230 KW power generation	Rs. 3,00,000/-

Total capital cost Rs. 14,40,000/-

Rounded to Rs. 14,50,000/-

II Cost of suggested condensing and cooling system (i. e. Rain type condensers with individual water jet air extractors and cooling tower) for 1250 TCD plant :-

i. Rain type condensers — 5 nos.	Rs. 1,75,000/-
ii. Air extractors — 5 nos.	Rs. 50,000/-
iii. Injection water pumps — 2 nos. (900 M ³ /hr. capacity)	Rs. 70,000/-

iv. Cooling tower pumpset — 1 nos. (900 M ³ /hr. capacity and 6 M head)	Rs. 25,000/-
v. Cooling tower (900 M ³ /hr.)	Rs. 3,03,000/-
vi. Cooling tower basin (110 M ² area)	Rs. 10,000/-
vii. Hot and cold water channels (Suitable for 900 M ³ /hr)	Rs. 30,000/-

Total capital cost Rs. 6,60,000/-

Round to Rs. 7,00,000/-

CONVERSION OF BAROMETRIC CONDENSERS TO MULTIJET CONDENSERS

By

H. L. Verma and V. K. Rohtagi

ABSTRACT

In all new installations, Multijet Condensers get preference over barometric condensers because of better and steady vacuum and elimination of a cumbersome air pump with all its high cost of operation and maintenance.

The over-all power consumption in multijet condensers is highest as compared to other barometric condensers. A system has been described in this article, by way of which the air pump can be eliminated and the existing barometric condenser can be worked with separate jet-ejectors without increase in power consumption. The proposed system works out to be the best in view of its simplicity and lower power consumption.

Introduction

A comparatively higher and steady vacuum in a Sugar Factory plays a very important role. It has been generally observed that while it is easy to maintain a steady vacuum of 660 mm. Hg., in multijet condensers, the vacuum usually fluctuates between 600 to 650 mm. Hg., with barometric condensers. The over-all power consumption is, of course, comparatively higher in multijet condensers basically due to the installation of a common high head pump for both the spray and jet nozzles. Unlike barometric condenser, it has its own

merit of not having an air pump which involves heavy operation and maintenance cost.

In order to combine the merits of these two types of condensers into one, it was felt necessary to discover a new system which involves minor modifications in the barometric system—hence this article.

Water Requirement

- (a) Multijet Condensers :—In a multijet condenser, there are two sets of nozzles, one for condensing the vapour and the other for evacuation. Though theoretical

requirement of water is much less, the practical figure is around 70 Kg./Kg., of vapour, about 45 Kg., for condensing and 25 Kg., for evacuation. The theoretical water head required for jet nozzles and condensing nozzles are around 24.5 meters and 15.2 meters W. G. respectively.

Since both the requirement of water are met with a common pump, a high head pump of about 24.5 meters W. G. is employed though bulk of the water required for condensing needs only 15.2 meters.

Basis

Pan Capacity	= 60 Ton/Strike
Heating Surface	= 300 M ²
Vapour/M ²	= 37 Kg./hr.
Vacuum	= 660 m. m. Hg.
Vapour/hr.	= $300 \times 37 = 11,100$ Kg.

(a) Multijet Condenser

Power required for pumping water :—

Water required for condensing	= 45 Kg./Kg., of vapour
	= $45 \times 11,100$
	= 499500 Kg./hr.

Say : $\frac{50 \times 10^4 \text{ Kg./hr.}}{\text{-----}}$

Water required for jet-nozzle	= 25 Kg./Kg., of vapour
	= $25 \times 11,100$

(b) Barometric Condensers :—Since in this arrangement the air and other incondensibles are evacuated by a separate pump, the water is required only for condensing the vapour. As stated above, about 45 Kg., of water is required per Kg., of vapour at a pump head of about 15 meters W. G., in this case.

Power Requirement

For the purpose of calculating the power requirement in both the cases, let us consider a standard pan of 60 Ton boiling 'A' massecuite.

$$= 2,77500 \text{ Kg./hr.}$$

$$\text{Say : } 28 \times 10^4 \text{ Kg./hr.}$$

$$\text{Total water required/hr.} = 78 \times 10^4 \text{ Kg./hr.}$$

$$\text{Total water required/Min} = 13000 \text{ Kg./Min.}$$

As all this water is required at 24.5 meter head —

$$\text{Theoretical power reqd.} = \frac{13000 \times 24.5}{102 \times 60}$$

$$= 52 \text{ K. W.}$$

$$\text{Actual power requirement at 70\% overall efficiency} = \frac{52}{0.7} = 74.3 \text{ K. W.}$$

(h) Barometric Condenser

(i) Power required for pumping water :—

$$\text{Water reqd., for condensing} = 50 \times 10^4 \text{ Kg./hr.}$$

$$\text{Head of water} = 15.2 \text{ meters}$$

$$\text{Theoretical power reqd.} = \frac{50 \times 10^4 \times 15.2}{102 \times 60 \times 60} = 20.7 \text{ K. W.}$$

$$\text{Actual power required at 70\% overall efficiency} = \frac{20.7}{0.7} = 29.6 \text{ K. W.}$$

(ii) Power required for handling air :

weight of air to be handled.

Air may either be evacuated with a reciprocating pump, sliding vane air pump, water ring air pump or water jet. Power required for different systems can be calculated only after ascertaining the actual volume and

There is a wide variation on the estimated quantity of air to be handled for vacuum creation. The figures given by different authors are as follows :—

Authority	Qty., of air present in 1000 Kg., of cooling water.	Qty., of air present in 1000 Kg., of vapours.
Weiss	0.026 Kg.	10.34 Kg.
Hausbrand	0.145 Kg.	8.80 Kg.
Badger	0.0136 Kg.	4.00 Kg.
Hugot	0.3 to 0.4 Kg.	10.50 Kg.
Horton		6.00 Kg.
Tromp		7.30 Kg.

PERK has adopted following formula for estimation of air to be handled by vacuum pumps (the formula gives figures closely tallying with 'Hugot' :—

$$L = (aw + bd)/10^6 \text{ Kg.}$$

Where L = Weight of air in Kgs.

$$a = 24$$

w = Weight of water

$$b = 960$$

D = Weight of vapours.

The weight and Volume of air handled has been calculated and plotted in graph I (Annexure 1)

Total Weight of Air/hr./1000 Kg. = 10.34 Kg. at 30°C injection water.

Total Volume of air/hr./1000 Kg. = 139 M³ at 660 mm. Hg.

∴ Volume of air handled/hr., for 60 T Pan. = 11,100 × 138 M³ hr.

$$= 1531 \text{ M}^3/\text{hr.}$$

Say : 1500 M³/hr.

Actual power requirement for reciprocating air pump, slide vane pump and water ring pump can be found from the Graph II. The Graph has been based on actual power consumption data supplied by the manufactures of the machines (Annexure - II).

Power requirement for different air pumps for handling 1500 M³/hr. of air may be found :

- | | | |
|-----------------------|---|-------------|
| 1. Sliding Vane | — | 31.25 K. W. |
| 2. Reciprocating pump | — | 22.5 K. W. |

Thus, total power consumed in three systems may be tabulated as follows :—

Sl. No.	System	Power Consumed		Total
		For Condensing	For Air handling	
1.	Multijet Condenser	—	—	74.3 K.W.
2.	Barometric Condenser with sliding vane pump	29.6	31.25 K.W.	60.85 K.W.
3.	Barometric Condenser with reciprocating pump.	29.6	22.5	52.1 K. W.

Modifications

Looking into the advantage of high vacuum of a multijet condenser on one hand and the wastage of power on the other hand, it was felt necessary to evolve a system in which the existing barometric condensers could be utilised as effectively as multijet condensers, but without any substantial increase in power consumption. Therefore, a trial was conducted in our factory by supplying water in multijet condenser through different sources, one at

higher pressure for jet nozzles and other a low pressure for condensing nozzles. The trial was carried out for about 15 days and the system worked quite satisfactorily.

Encouraged by the results, 6 Nos. jet ejectors were locally fabricated and installed alongwith the barometric condenser of 4 Pan and 2 Evaporator Sets. The air line of the condenser to air pump was disconnected and got connected with the ejector. The ejector was supplied with water at 24.5 metre head.

Power requirement in the case under study : —

Power for condensing	—	29.6 K.W. (as in the case of barometric)
Water required for jet nozzles	—	28×10^4 Kg./hr.
Water head	—	24.5 meters
Theoretical power requirement	—	$\frac{28 \times 10^4 \times 24.5}{102 \times 60 \times 60} = 18.7 \text{ K.W.}$
Actual power requirement at 70% efficiency	—	$\frac{18.7}{0.7} = 26.71 \text{ K.W.}$
Total power requirement	—	$29.6 + 26.71 = 56.31 \text{ K.W.}$

Observations :

power consumption in the system also compares favourably with other system.

The system worked satisfactorily. It took about 7-8 mts., for creating a vacuum of 18'' and 17-18 mts., to a vacuum of 26.5''. The

Different systems may be chosen in the following priority according to power consumption :—

- | | | |
|---|---|----------|
| 1. Reciprocating pump with barometric condensers. | — | 52.11 KW |
| 2. Separate nozzle ejector with condenser. | — | 56.31 KW |
| 3. Slide Vane pump with barometric condenser. | — | 60.85 KW |
| 4. Multijet Condenser. | — | 74.3 KW |

Conclusion

From the trials conducted in our factory, the following conclusions can be drawn :—

- (1) The existing barometric condensers can be converted to multijet condensers by the addition of a separate multijet ejector to the existing condenser and eliminating the air pump.
- (2) The wastage of the electrical power in multijet condenser can be avoided

supplying condensing water through a separate low head pump.

- (3) Since there is practically no rise in the temperature in the ejector water, it can be taken straight to the injection water pit thus reducing the load on spray pump.
- (4) The conversion can be easily and economically carried out in the existing old system without condemning the barometric condensers.

- (5) In view of its simplicity, lower power consumption and steady vacuum, the system should be adopted in case of new installations also.
- Deputy Managing Director, and Shri R. Sahai for according permission for the publication of this work.

Acknowledgement

We are grateful to Lala Bansi Dharji,

We are also thankful to Mr. Man Mohan, General Manager, for his keen interest in the work.

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ANNEXURE—I

Weight and volume of Gases/1000 Kg, vapour consumed

(For Injection Water at 30°C)

Vapour Temp. C°.	Gas Temp. C°.	Cond. inlet Vac. MM Hg.	Outlet Cond. Pr. MM Hg.			Sp Vol. M ³ /Kg.	Kg. Air	M ³ Air
			Total	Vap.	Air			
45	35.5	668	66.9	43.4	23.5	28.33	10.76	305
46	35.6	685	70.7	43.6	27.1	24.52	10.67	262
47	35.7	681	74.6	43.9	30.7	21.65	10.59	229
48	35.8	676	78.7	44.1	34.6	19.33	10.52	202
49	35.9	672	83.0	44.4	38.6	17.23	10.46	180
50	36.6	668	87.5	44.6	42.9	15.51	10.41	161
51	36.1	663	92.2	44.9	47.3	14.07	10.36	146
51.5	36.0	660	95.15	45.0	50.1	13.45	10.34	138
52	36.2	658	97.1	45.1	52.0	12.83	10.32	132
53	36.3	653	102.2	45.4	56.8	11.72	10.28	120
54	36.4	648	107.5	45.5	62.0	10.74	10.25	110
55	36.5	642	113.0	45.8	67.2	9.92	10.22	101
56	36.6	636	118.8	46.0	72.8	9.16	10.19	93
57	36.7	630	124.8	46.3	78.5	8.49	10.17	86
58	36.8	624	132.1	46.6	85.5	7.8	10.14	79
59	36.9	618	137.6	46.9	90.7	7.36	10.12	74
60	37.0	611	144.4	47.1	97.3	6.86	10.10	69

ANNEXURE-II

Power Consumption of Air Pumps

Sliding Vane

Model	Capacity M ³ /hr.	Power Consumption (KW)
V-80	806	15
V-230	1650	33.75
V-230	1980	40.5

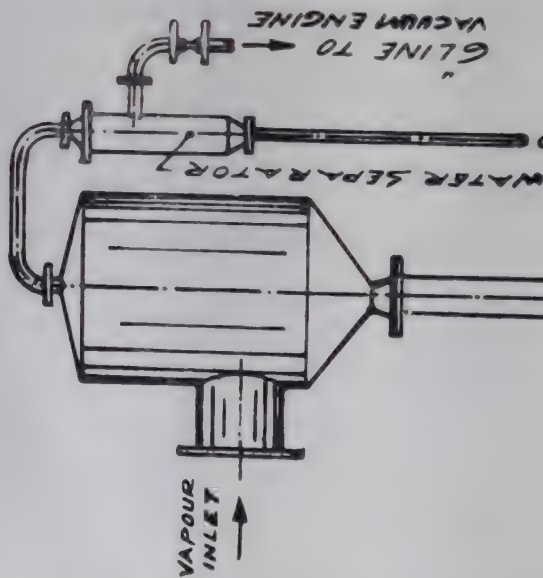
Water Ring

W.V. -100	520	25.87
M.V. -150	980	39.0
M.V. -200	1450	25.5

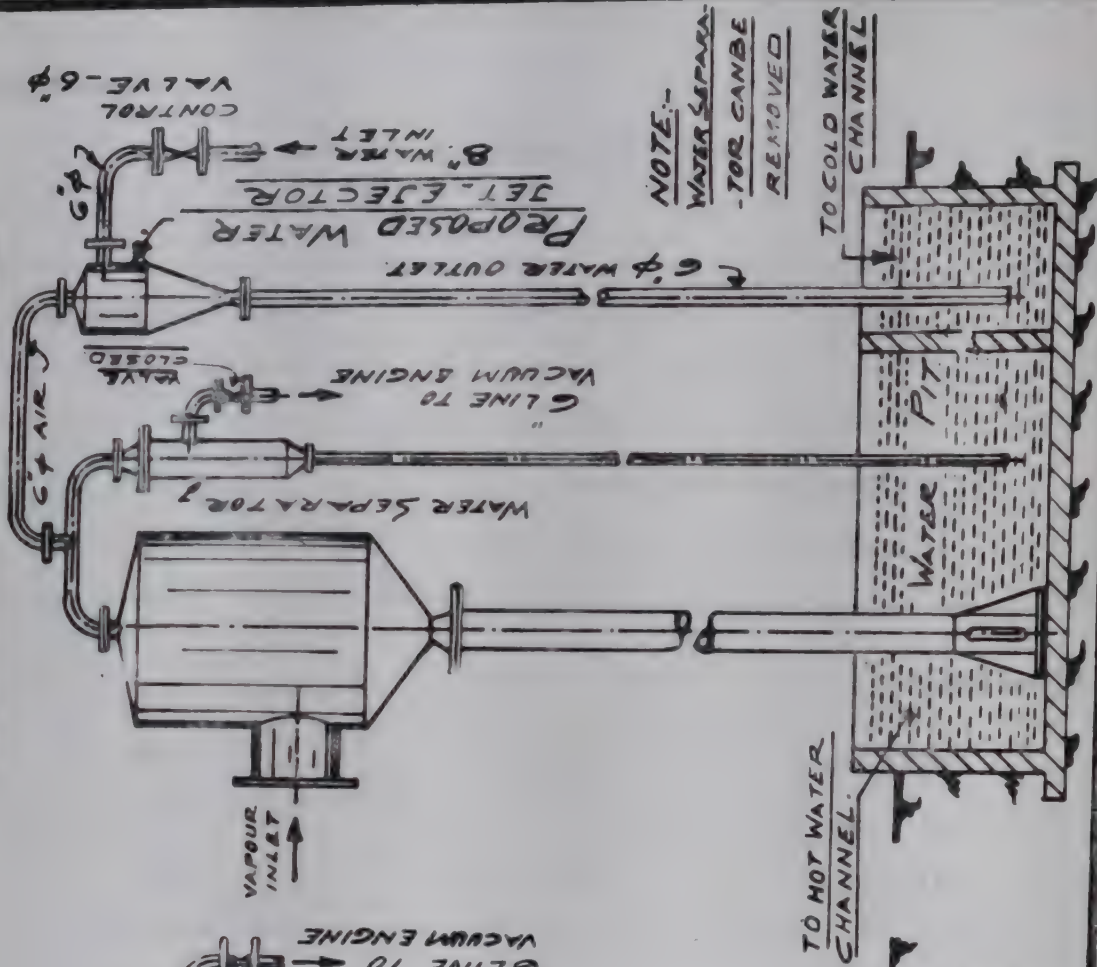
Reciprocating (Non-compensating)

1000	15
1500	22.5

OLD ARRANGEMENT



MODIFIED ARRANGEMENT



NOTE--

WATER SEPARA-

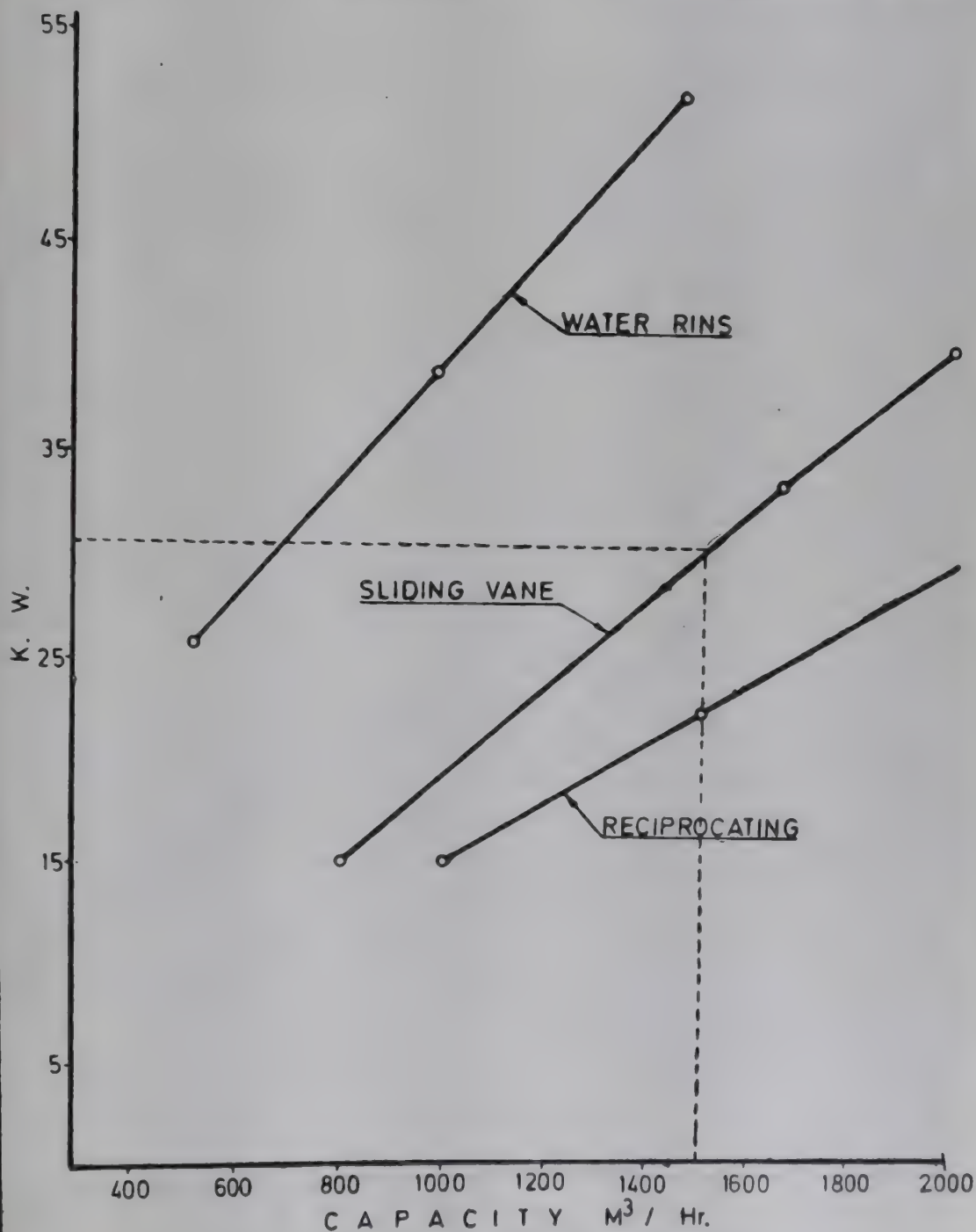
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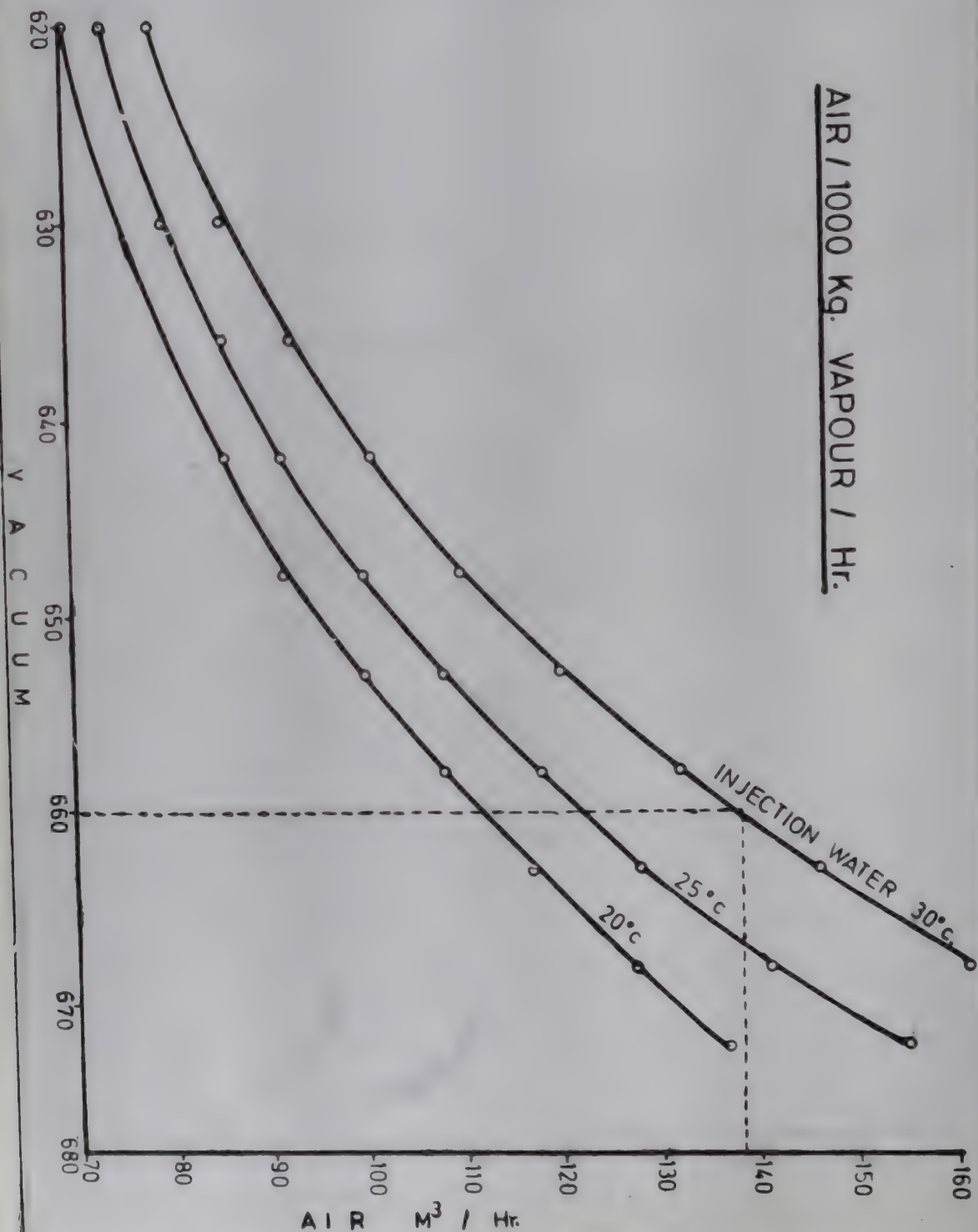
TO COLD WATER

CHANNEL

VACUUM PUMP POWER CONSUMPTION AT 660mm. Hg.



AIR / 1000 kg. VAPOUR / Hr.



A BETTER CONDENSING SYSTEM

By

Anil C. Chatterjee and G. Kashinathan

ABSTRACT

A Condensation system that drastically reduced the water and power consumption in the injection and spray system is discussed. The best results that will indicate good performance as given by different authors and the best figures that can be achieved by the suggested system are dealt with. The overall advantages have been explained.

Introduction

The recent trend in adopting the age old counter current condensers and vacuum pump may be viewed as retrograde step, but it is not so. Not long back, most of the sugar factories were using a central condensing system, consisting of a large counter current condenser and a dry air pump. Some of the North Indian factories do still retain that system. Inspite of the fact that such a system has less number of units to be maintained, requires less space, consumes less water and power than several individual condensing units, the system was dispensed with in favour of the simple multi jet condenser mainly because of the fact that a central condensing system caused serious fluctuations in vacuum impairing boiling operations and promoting enteraintment. Moreover the simplicity of

the Jet condenser was a favourable factor in this direction inspite of the multiplicity of units.

The present recommendation of individual counter current condenser with a rotary vacuum as a replacement to the Multi Jet Condenser system, has several advantages to the sugar industry.

1. It reduces the water consumption drastically.
2. This in turn reduces the number of pumps and cost of pumping considerably.
3. Spray pond or cooling tower capacity required will also be reduced correspondingly.
4. Overall there will be considerable savnig in power consumption also.

5. The system enables better control of vacuum to the unit.
6. In spite of the addition of a vacuum pump to each unit, the total cost for the installation will not be more than the Multi Jet system, it may be even less.
7. This system is less sensitive with regard to water temperature than the Multi Jet Condenser.
8. It is less sensitive with regard to air leakages than the Multi Jet system.

Design Consideration

The design of such condensers should have the following features incorporated in order to achieve best performance.

- a) It should expose as large a surface as possible to the vapour flow, in order to effect maximum condensation of vapour.
- b) As far as possible, the design should ensure least difference in the vacuum between the vapour inlet and the top of the condenser from where the air/vapour mixture is removed.
- c) It should cool the air leaving the condenser as close to the temperature of injection water as possible. Hence an ideal condenser that can develop 100% efficiency will be one in which—
 - i) The temperature of the water leaving the condenser through

the tail should be the same as that of the vapour — this will ensure minimum water requirement.

- ii) The air should leave the condenser at the same temperature as the injection water — this will ensure that the air volume is least.
- iii) The vacuum at the vapour inlet side should be equal to the prevailing conditions.

These are the ideal conditions and it will be the designer's endeavour to reach as close to these conditions as possible in order to obtain the best possible performance.

Conditions Achievable

For example, if the tail water temperature can reach the temperature of the vapour, the efficiency will be 100%. But though this ideal condition can not be reached, it is necessary to reach as close to this ideal condition as possible viz. to achieve a very small temperature difference. The thoroughness of the mixture between the injection water and the vapour has a bearing upon this, and the better the condensing performance, lower will be the temperature difference. The vacuum obtained will naturally be influenced by the tail water temperature. Various authors have expressed the minimum temperature difference that should be achieved by a condenser for best performance.

According to		Temperature difference between vapour and tail water.
Weiss	...	2°C
Hugot.	...	5°F.
Lyle.	...	2°C
Webre.	...	5-25°F (15°F)
Tromp.	...	5-20°F (10°F)
Perk.	...	2-3°C

Values of 2 - 3°C are normally obtained.

In the same way, to obtain the least volume of air leaving the condenser, the air should be cooled down if possible to the temperature of the injection water. This again is too ideal, the air temperature being always slightly higher than that of the water. This difference in temperature as expressed by different authors is listed below :—

According to		Temperature difference between air leaving and injection water.
Weiss.	...	4°C
Webre,	...	6°C.
Hausbrand.	...	5°C.
Tromp.	...	0°C.
Hugot.	...	0°C

Probably in the opinion of Tromp and Hugot the air is expected to be cooled down in transit between the condenser top (from where it is tapped) and the vacuum pump to the temperature of injection water. In practice, values closer to the one suggested by Tromp and Hugot are achievable.

The third ideal condition to be obtained viz. that the vacuum should be same at the

vapour and air lines is obviously too ideal to be achieved. Authors like Perk suggests that with a well designed and adequately loaded condenser, the difference should not be more than 5 mm. Hg. He also points out that with over-loaded and loaded condensers, the difference may be quite larger.

The closer we reach these ideal conditions, the lesser will be the quantity of injection

water required, lesser will be the volume of air to be handled by the vacuum pump, and higher will be the vacuum obtained.

Typical Condensers

The quantity of water required will depend upon the vapour load, vacuum required; temperature difference obtained between tail water and injection water etc. In turn all these factors depend on the design of the condenser and the temperature of injection water.

Various designs of the counter current barometric condensers are in use in different countries, but we restrict ourselves to the multi tray rain and shower type condenser and the rain type single tray condenser.

In both the designs, the air leaves the unit at the end where the water enters and vapour entry is at the lower of the condenser. Both designs expose a large surface to the vapour flow for condensation but in a different ways.

The Multi-tray Rain and Shower type (Fig. No. 1.)

In the multi-tray rain and shower type condenser, injection water is dispersed finely into rain by means of a circular perforated tray which also provides a curtain of water at its periphery. In order to increase the flow path of the vapour-air mixture, several perforated half trays are interposed in such a way that the rain water passes over these trays, which in turn continue to dispense the water in showers and curtain at each tray. This provides a very large surface area of water particles to come into contact with vapour, thus maintaining a very effective condensation.

The single tray rain type. (Fig. No. 2.)

The rain type single tray condenser, consists only of a full plate, perforated by numerous holes with a central opening for air passage. This tray receives the injection water, and divides it into several rain particles which travel right upto the tail pipe in a finely dispersed condition.

This long path of rain enables the vapour to come into contact sufficiently with water, at the same time keeping the flow of air vapour mixture uniform. The design provide sufficient transit time for the water particles to condense the up coming vapours.

The condensers can be connected to a rotary water ring vacuum pump which will evacuate the air mixture continuously. Surges in both these types can be avoided by proper design features. These condensers should be reasonably dimensioned so that the resistance to air passage is minimum and the transit time for the air-vapour mixture is sufficiently high.

Comparison

As the net head against which the pump is to work, will be lowered due to the effective vacuum created by the pump, the HP required for the injection water pump of same capacity will be very much on the lower side. At the same time, it is to be mentioned that these types of condensers require only 1/2 the water quantity normally supplied to Jet condensers. This will in turn reduce the size of the tail water cooling system. It is preferable to provide liberally designed cooling towers

last end of spray ponds, so as to obtain a lower injection water temperature.

Especially where factories are short of water and power this system of counter current barometric condenser with water ring vacuum pump can be of immense help. The addition of a vacuum pump to each unit does increase the number of units to be maintained and also additional power; but the net saving in power, equipment etc. will be a definite advantage over the multi jet barometric condenser system. As far as additional maintenance is concerned, it is to be specified here that these vacuum pumps, if supplied with good quality seal water

are trouble free, requiring least supervision, can be operated nonstop throughout the season can be mounted as close to the condenser as possible. All these advantages weigh in favour of this system in spite of the additional vacuum pump required.

Selection of vacuum pump

The selection of the vacuum pump naturally depends on the volume of air to be handled. It is generally preferable to adopt the following tables as given by Hugot for determining the quantities of vapour to be handled by system and the quantities of air displaced.

Evaporation rates to be adopted for selecting air pump for vacuum

pans	...	lbs/sft. hr.
A — Pans	...	10
B — Pans	...	9
C — Pans	...	6.5
Multi effect	...	To be determined on the basis of bleeding.

Weight of air to be extracted.

For a central condensing system	...	8 - 10 lbs/1000 lb. of vapour.
For 2 or 2 pans or multiple effect	...	6 - 8 lbs/ —do—
For a single pan	...	5 - 6 lbs/ —do—

These tables can be taken as a guide and where exact quantities can be determined, they should be substituted.

Acknowledgement

The Authors record their sincere thanks to the Management of Walchandnagar Industries Ltd. for the encouragement and keen interest in the development work.

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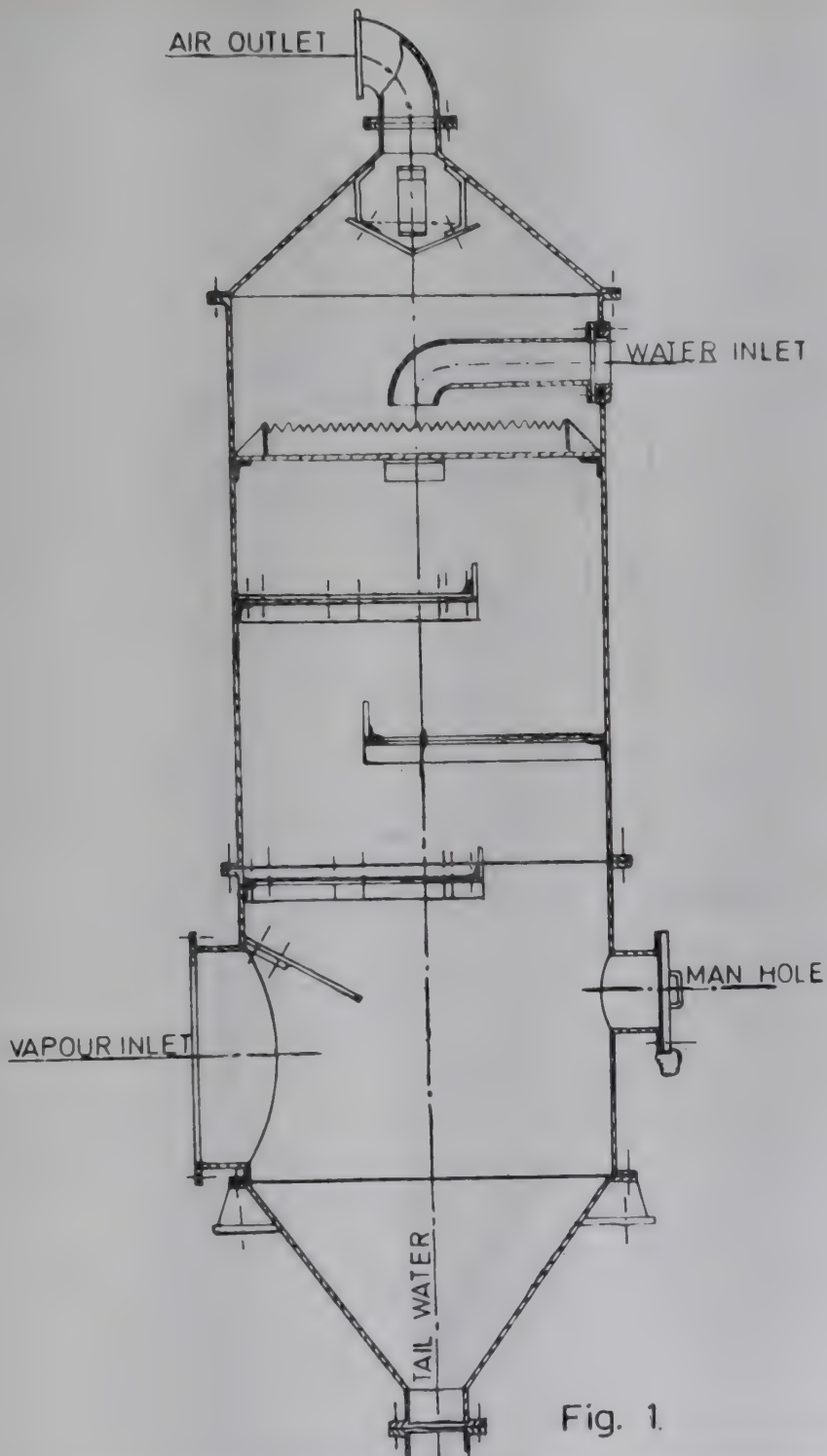


Fig. 1.

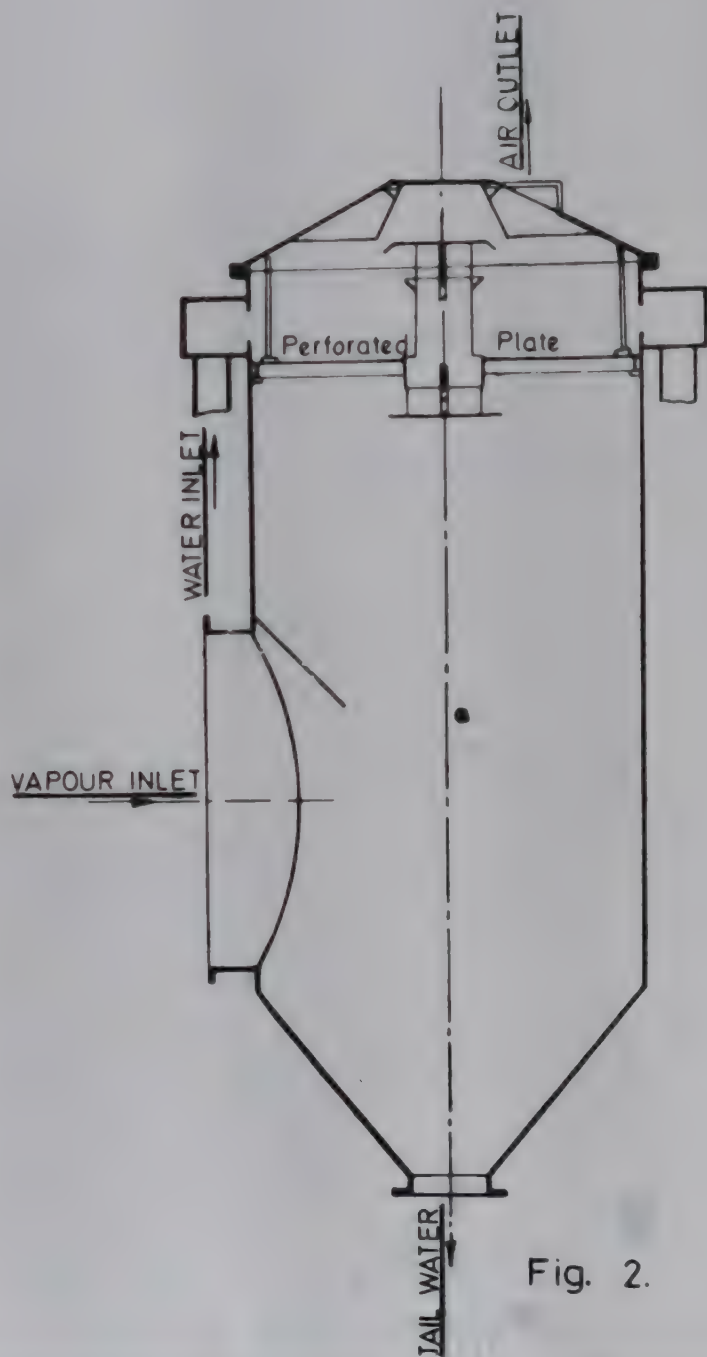


Fig. 2.

INTRODUCTION OF COOLING TOWERS IN SUGAR INDUSTRIES

By

K. K. Menon

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ABSTRACT

Where the cold water is not available in plenty it is necessary to cool the warm water leaving the condensor and return it for cooling again. To a large extent therefore, the cooling water temperature determines the vacuum condition. While many systems are in vogue, the system generally used in Sugar Industry is spray pond. Of late, Sugar Industry has started introducing Mechanical Draft Cooling Towers. The advantages and disadvantages of both the systems and the principles involved are discussed. Considering the economics it would be better if the new Mechanical Draft Cooling Towers replace the conventional spray pond from the Sugar Industry.

Introduction

In the process of Sugar manufacture, the maximum efficiency of evaporation is obtained in operating the multiple effects and pans under vacuum. The common equipment to achieve this is the condensor, which requires a copious quantity of cool water to ensure condensation of the vapour produced from the evaporating vessel. The vacuum condition therefore, mainly depends on the temperature of the cold water. Most of the factories in India (Where the cold water is not available

in plenty from river or sea) it is necessary to cool the warm water leaving the condensor and return the same at a lower temperature as cold inlet to condensor. Since majority of the factories work in summer months as well, it was found extremely difficult to obtain the desired degree of temperature and it, therefore, affects the performance of boiling house. It is customary to employ cooling system and the most commonly used in Indian Sugar Industry are the spray ponds. There are certain inherent disadvantages in this system and the more efficient cooling system like

Mechanical Draft Cooling Towers are being introduced.

Different Types of Cooling Systems :

The principal types of cooling systems are (1) Spray Ponds and (2) Cooling Towers. Unlike Spray Ponds, the Cooling Tower never rely on a wind condition for cooling and hence can be accurately sized and selected for the specific performance.

(1) Spray Ponds :

Spray Ponds are large flat basin above which the warm water is distributed by pipes on which the spray nozzles are arranged at regular intervals. When water is sprayed, the water is brought into contact with the atmosphere and a small portion gets evaporated. This evaporation as well as the contact of ambient air with fine drop of water, produce required degree of cooling. Theoretical heat removal per pond of air circulated in a system depend on the temperature and moisture content of air or in other words it is the wet bulb temperature and it is this temperature that is the lowest theoretical temperature to which water can be cooled. Hugot has given the efficiency ρ as

$$\rho = \frac{t_2 - t_1}{t_2 - t_0}$$

t_2 = Temperature of warm water entering Spray Pond.

t_1 = Temperature of cold water leaving Spray Pond.

t_0 = Wet bulb temperature.

Even in a very generously designed Spray Pond operating under ideal conditions, it is seldom possible to achieve efficiencies higher than 50–60%. This means in most of the cases, the cold water temperature from a Spray Pond will be mid way between the hot water temperature and the ambient wet bulb temperature.

(2) Cooling Towers :

In case of Cooling Tower, the theory of heat transfer is the one developed on Merkel, whose analysis is based upon "Enthalpy Potential Difference" as the driving force. Each particle of water is enveloped by a film of air and the enthalpy difference between this film and the surrounding air provides the driving force for the process of cooling. The Cooling Towers accomplish the cooling due to a constant flow of ambient air predetermined to cool the water with high capacity draft fans, and the remainder of water circulated is cooled through latent heat transfer. There are both natural as well as mechanical draft towers in existence. Among the mechanical draft towers the induced draft towers are considered as most efficient than that of the forced draft towers. The flow arrangement viz. counter flow and cross flow have further classified this design. Thermodynamically a counter flow, induced mechanical draft fan is the best, since

the coldest water contacts the coldest air and thus the maximum enthalpy potential. However, from practical consideration, and the experience obtained in working with a cross—

flow type, we feel that the cross—flow design offers more efficient and compact system because of lower static pressure losses through the Cooling Tower.

Instaliation and Working of a Cooling Tower :

The Cooling Tower supplied to us have the following specification :

Model : 473 — 204 (Sl. No. 73-2-038) — Cross—Flow Design.

Capacity : $4 \times 12,000$ Litres/Minute.

Hot water temperature : 120° F (49° C)

Cold water temperature : 93° F (34° C)

Design Wet bulb temperature : 77° F (25° C)

Fan : Type	:	Marler H. 3—9
Dia	:	4260 mm
Pitch	:	38.5°
Meter	:	Kirlosker, H. P. : 35.

Plan Air

Width	:	10.4 Metres.
Length	:	24.5 „
Height	:	5.4 „

At basin level the width is reduced to about 8.0 Metres.

The Author had the privilege of working with both Spray Pond and this Cooling Tower and the efficiency of the later has improved the working conditions very much. The difference in temperature of hot and cold water is termed as 'Cooling Range' and the diff-

erence between cold water temperature and wet bulb temperature is called 'Approach'. Data collected from the working of Spray Pond and Cooling Tower at an identical wet bulb conditions are appended below.

Spray Pond Performance

Wet Bulb Temperature : 79° F

S. No.	Range	Approach	S No	Range	Approach
1.	5° F	5.5° F	4	24° F	20° F
2.	12° F	12° F	5	28° F	21° F
3.	20° F	16° F	6	30° F	21.5° F

Cooling Tower Performance

Design Wet Bulb Temperature : 79° F (Only 3 Cells working).

S. No.	Range	Approach	S No.	Range	Approach
1.	18° F	10° F	5	25° F	11° F
2.	20° F	3° F	6	27° F	5° F
3.	22° F	12° F	7	29° F	9° F
4.	24° F	7° F			

It is clear from the above data that Spray Pond is unable to cope up with large cooling ranges because of its inability to produce low approaches and the approach increases as the range increases and hence not suited for high cooling ranges.

For our Evaporators and Pans we have fitted 'Built in Condensers', and while preparing the layout the hot water channel was constructed at a height of 6.75 Metres and hot water has been directly taken into the Cooling Towers. This has saved the trouble of pumping hot water to the Tower and subsequent saving of Power. By providing proper baffles at each cell, we could easily maintain an equal flow and distribution over the basin of all the cells of the Tower. Care was also taken to keep sufficient water depth in cold water collection basin to prevent secondary air entering the suction under normal operation. General view of the Tower is shown in face 'A' of the enclosed drawing. The water inlet is adjusted by the control valve on the top. Water is distributed through various nozzles and allowed to intimately mix with exhaust air before dropping to the deck below. The feed of water is interrupted by the slat type Grills as it flows counter currently to the air (See Table D)

Advantages Vs. Disadvantages

The merits demerits of the existing Spray Pond when compared to the new Cooling Tower introduced are as follows :

Spray Pond

1. This is most commonly used in sugar industry.

2. It has got a very aesthetic appearances.

Against this, it has the following disadvantages :

1. Area required is 20 times larger than that of the mechanical draft Cooling Towers.
2. Inability to cope up with large cooling ranges.
3. Performance depends on atmospheric condition and wind velocity.
4. High drift losses to the extent of 3-5 % and finally.
5. Heavy maintenance.

Cooling Towers

1. Require less space.
2. As seen from the actual performance chart on range and approach, this can operate on a wider 'Range' and 'Approach'. The desired temperature of cold water is maintained even as low as 30° F approach, irrespective of atmospheric condition.
3. The drift losses are very low at 0.2% when compared to 5% losses in Spray Ponds.
4. Saving in piping cost, because cooling towers can be located very near the plant building. Similarly, the pipe diameters are considerably reduced because of lower flow rate.

5. Saving in the cost of pumps, because the flow rate goes down with lower cold water temperature attainable in cooling towers. In addition to this, because of the low height of the cooling tower, it is possible to bring the return hot water to the cooling tower from the condensers and pans by gravity, thereby eliminating the hot water pumps completely.

Conclusion

Considering the working conditions of the the sugar plants during hot summer months and the high temperature conditions prevailing, it becomes essential to introduce high efficiency mechanical draft Towers of counter flow or cross flow types. As process refinements and advancement have been approached in this industry, we have now a task of demanding more closer control of its production units. The effective cooling system is the major source of high vacuum conditions and decrease the process difficulties. It is, therefore, required to introduce a cooling system that would apply cold water of desired temperature irrespective of climatic variations and thus stabilize the process conditions.

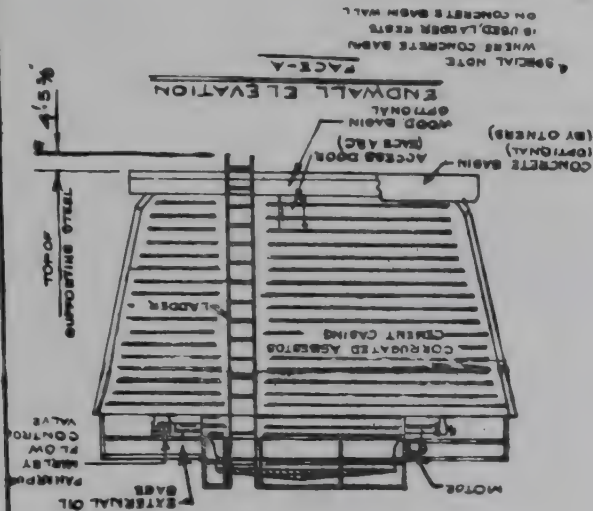
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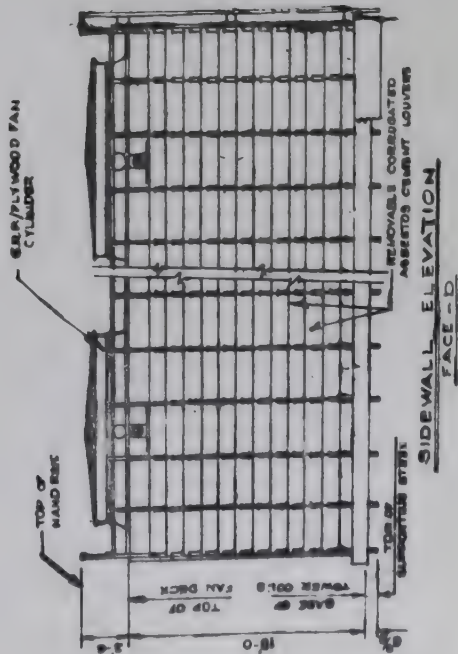
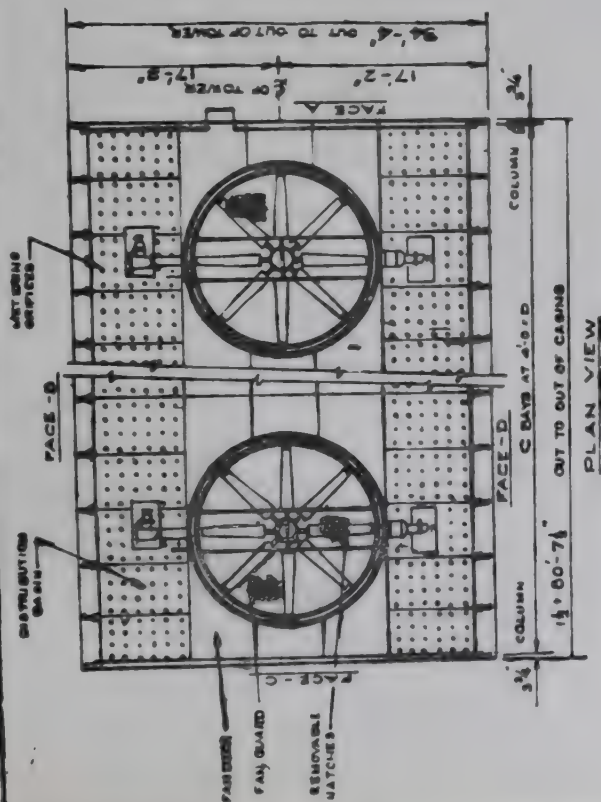
The Mechanical Draft Cooling Towers are compact and require less maintenance. Its initial high cost compares favourably with Spray Pond, provided, we take into account the non-availability and high cost of the land required, the drift losses, which could have other wise required to pump extra cost. Considering the advantages, economy and other aspects of the two systems, we should consider the techno-economic viability in continuing the existing system and to introduce the more efficient equipment. The mechanical draft cooling towers have to slowly replace the conventional Spray Ponds from sugar industry.

Acknowledgement

The Author wishes to express his deep sense of gratitude to the Managing Director, and the General Manager of Sri Chamundeswari Sugars Limited, Karnataka (India), for their keen interest and permission to publish this paper. The Author also wishes to thank Mr. V. Swarup, Sales Manager of Messrs. Paharpur Cooling Towers Private Limited, Calcutta for his necessary help rendered in completing this article.



COOLING TOWER 473-204
 M. CHAMUNDESWARI & SONS LTD.,
 K. M. DODDI, MADUR TALUK, MANDYA DT.,
 KARNATAKA STATE



SCHEMATIC VIEWS
 MODELS 473-204 THRU 475-203
 SERIES IS WOOD B.F.
 PAMARPUR COOLING TOWERS (P) LTD.
 CALCUTTA, INDIA
 DATE 2-4-55
 DRAWN BY M.J.R.
 CHECKED BY R.G.R.

TRACED BY: *B. Srinivas* 6.2.76



A NEW CONCEPT IN REGARD TO THE MANUFACTURE OF MILL ROLLER C. I. SCRAPERS

By

V. S. Joneja

Supdt. Engineering Works Ltd. Sugar Unit
Khatauli

ABSTRACT

The paper stresses the improvement in the design of the C. I. Scrapers. The improved design results in better scraping of bagasse with minimum wear to the mill rollers.

Introduction

The C. I. Scrapers are being used for scraping of bagasse from the grooved rollers in the Mill House all over the world. The Author has made an improvement in the manufacture of scrapers which has resulted in better scraping of bagasse and also minimising the wear of the rollers.

The scrapers are generally grooved according to the pitch and depth of the rollers but if after cutting the grooves on the shaper machines, the depth of the grooves is increased with the help of a square tool in such a way that the width at the bottom of the groove is kept about 25 to 30% of the pitch and depth about 9 mm or a little more as shown in the sketch attached. There will be defini-

tely improvement in the working of the Mill as follows :

- (1) Wear of the rollers will be minimised as the scraper teeth will only touch in the grooves of the rollers resulting increase in the life of the rollers.
- (2) The rollers will remain rough throughout the season as the scraper will not touch with the roller at the top, thus will not require re-grooving during the season.
- (3) The bagasse grip of the roller will rather improve considerably as compared to the grip at the starting of the grinding.
- (4) The life of the scraper will also be increased.

STUDY OF HEADSTOCK DESIGN

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ABSTRACT

The article discusses various factors in vertical and inclined headstock. Though the inclined headstock is claimed as the latter development here it is found that conventional vertical headstock is much better than inclined headstock in the milling performance and maintenance. The relevant points are given a careful study.

Hydraulic Load Distribution

It has been a conventional practice and also been proved that the performance of a milling, as far as extraction is concerned, is better and proportional to the effective hydraulic load applied on the bagasse blanket. The effective resultant of the hydraulic load is maximum at vertical headstock and it is definitely less in inclined headstock proportional to the shifting of top roller.

It is claimed that the inclined head stock assists in the free floating of top roller and it is in the line of reaction of hydraulic load, but in case of vertical headstock for the same hydraulic load the reaction is converted to vertical component. Considering the components for inclined and vertical position, the value of the load component is more in case if it acts vertically than when it is inclined. So at the cost of reduced hydraulic load, there is

a flotation of top roller. This means reduction in extraction may it be pol, Brix or juice. This is because of the simple theory that the thrust reached from the bagasse to lift the roller vertically is more than to lift the roller 15° inclined to the vertical axis. Because of the free lifting of top roller at 15° inclination to the top vertical axis, the losing part of the hydraulic load on the bagasse which should have acted on the bagasse if it were to be vertical, is not subjected to the total effective hydraulic load. This lapse occurs more on the delivery end where the bagasse should have been under heavier load otherwise. Hence this system of loading is a little inactive in primary mills and much more in case of latter mills due to increasing fibre loading.

Generally we adopt a practical factor as the ratio of feed to discharge when we work out the work opening, But it is practically not possible to maintain constant load in the Mills.

At different loading conditions the ratio factor is varying. The enclosed diagram (Fig. 1) clearly shows the changing ratio. Though the increase in opening is observed in vertical headstock also, it is same both in feed and discharge but in inclined headstock the change is more in delivery.

Strain on Trash Plates and Fittings

In vertical headstock the load is distributed radially and is almost distributed evenly from the feed end till the exist of the Bagasse from the discharge. (Refer fig. 2

This even distribution helps proportional and uniform development of stress by the material, viz. Roller-Trash plate, trash, beam and other related fittings. In inclined headstock as the top roller is shifted away from the centre towards the feed side, the even distribution is disturbed, and undalanced development of stress takes place. This condition instead of allowing the load axis to act radially tries to shift it tangential the profile of the trash plate. But to this tangential force heavy damages is caused to the trash plate and fittings. The meshing of the trash plate to the feed roller gets disturbed and this is the main cause of shearing of trash plate bolts (bolts fastening the trash plates to the Trash beam) Normally it gets sheared at the counter sunk portion). The shearing of the trash plate bolts causes long stoppages with possible damage to the trash plate. Apart from this the tangential force causes some sort of vibrations and snoring sound in the Trash plate fittings.

As the centre of the top roller moving away from the vertical axis of the headstock

the load is unevenly distributed in the head stock itself. A part of this load is acting vertically on the cantilever portion of the headstock and hence there is an uneven load on the head stock foundation bolts which always tries to tilt the headstock towards the feed side. From this it is obvious that the foundation bolts in discharge side are subjected to unevenly changing load (Fig. 3 may be referred.)

Uneven Meshing of the Pinion

Another notable disadvantage is the improper meshing of the driving pinions. As the top roller is shifted towards the feed, the area of contact due to constant side thrust between the top and feed roller pinions increases the area of contact. This causes some sort of rubbing and spoils the profile of the pinion which inturn increases the frictional load.

The Impact on the Intercarrier Design

It has been universally accepted that the proper feeding angle is absolutely essential for efficient feeding of Bagasse at the feed end. An approach to get an efficient feeding has resulted in good lot of design in intercarriers. In case of inclined headstock the feeding angle is seriously affected due to the lift of the top roller towards the feed side. In this case the top roller angle also gets changed though we set evenly at rest. So due to the change of top angle the feeding angle also gets disturbed which in turn creates the hesitation of magasse movement at the feed end.

Working Facilities

While in case of straight headstock the

lifting of top roller is simple. Since it can be easily handled by overhead cranes during overhaul and repairs. The same is curbed in case of inclined Headstock. The time taken even for replacing a hydraulic bucket is much more in case of inclined head stock even when it is handled by a skilled workmen as the cranes has to be offset and the fittings to be removed tactfully. Similar is case when the top roller is removed as also fitting of the top roller bearing. In all these cases the positioning of the chain block and hence the crane has to be coincided with the reaction line. This requires much labour and technique which makes a simple job more complicated at times.

Conclusion.

We have made the comparative study of inclined and vertical headstock with our

experience in various factories on both these types. Out of our experience we practically find that eventhough the inclined headstock has said to be the latest improvement over the vertical headstock, in practice we find that in operation the vertical headstock is more efficient which is evident from the points discussed above.

Acknowledgements

We take this opportunity of thanking our beloved Special Officer Mr. P, Paramanondan, B. Sc., (Ag.) for his untiring encouragement he has shown us for bringing out this paper.

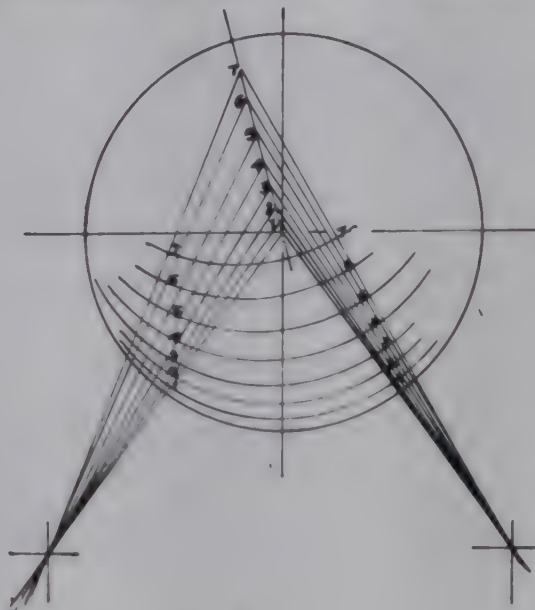
The authors also thank Mr. V. Jayaraman, Doughtsman for excellent cooperation given in making the drawings and also helping us to study the design aspects.

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LIFT IS NOT PROPORTIONAL IN INCLINED HEADSTOCK



= 0.6600
 = 0.6786
 = 0.6897
 = 0.6958
 = 0.7033
 = 0.7143
 = 0.7184

FIG 1

LINE OF ACTION TANGENTIAL TO TRASH PLATE

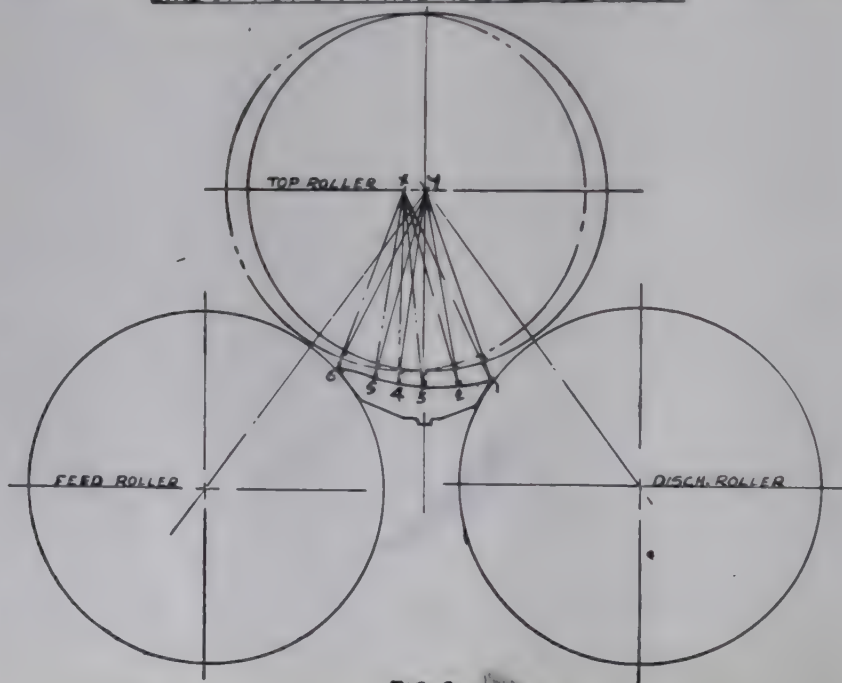
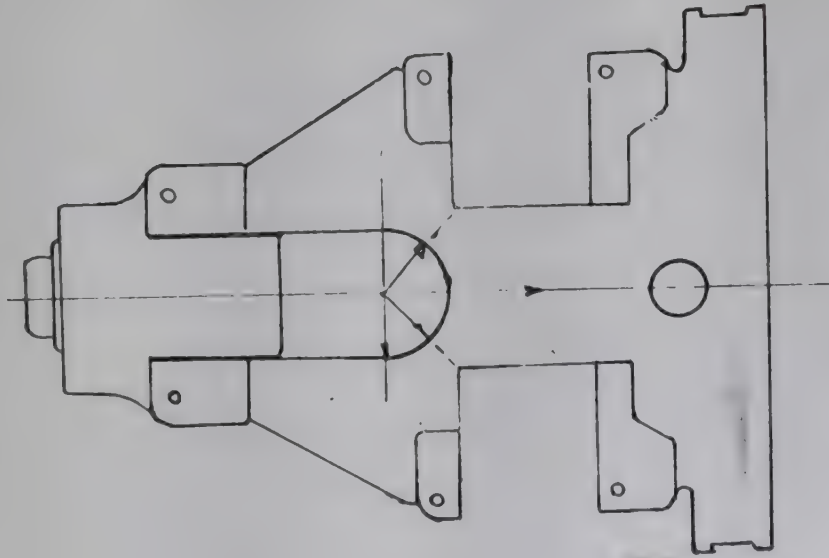
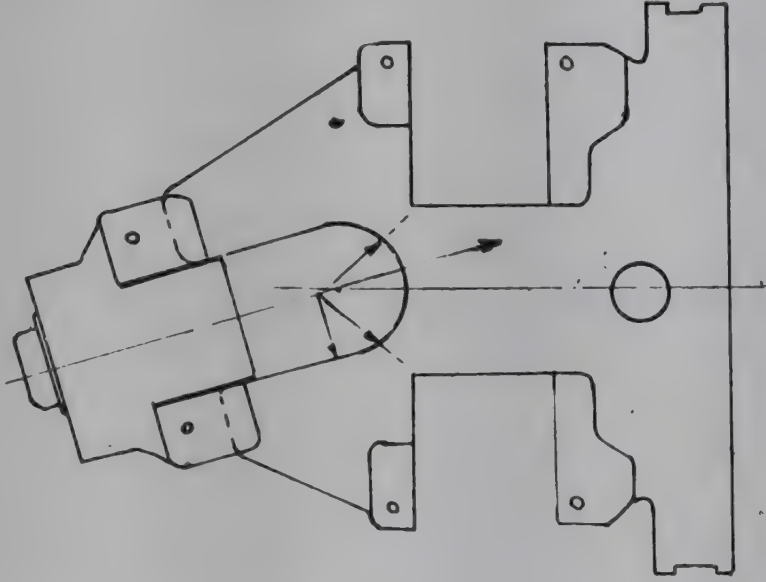


FIG 2

UNEVEN DISTRIBUTION OF LOAD IN HEADSTOCK.



VERTICAL HEADSTOCK.



INCLINED HEADSTOCK.

FIG. 3

Paul

BALANCING OF THE ROTATING MACHINERY IN SUGAR INDUSTRY

By

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Andhra Pradesh

ABSTRACT

It is needless to emphasis the importance of balancing the rotating Machinery in any Industry. The life, performance and accuracy of a machine primely depend upon as to how the moving parts in it are adjusted, balanced and set.

In the accompanying short article, I have briefly described the method of balancing the Cane Leveller and Cutter in their position. I have also suggested a small device for balancing the Centrifugal pump inpellers, Bagassilo and vapour blowers etc. The device cane easily be prepared in any workshop. I am sure that this article will be of much use to one and all the practising Engineers in the Sugar Industry particularly to those who are on the maintinence side.

Introduction

Any Rotating Machinery running at certain speed should necessarily be balance d. This rule applies in Sugar Industry also to all the Rotating Machinery right from the cane cutters to the Sugar grader. The imbalance in weight creates vibration in the machinery, thereby leading to its major break downs, like breaking

of the foundation bolts, shafts or bearings etc., which causes lot of inconvienience to the Engineer and great loss to the industry.

Every sugar factory may not have sensitive balancing machines. So, a simple balancing machine as shown in the sketch can be prepared in any workshop. This simple device is useful in testing the balance of centrifugal

pump impellers, baggassilo and vapour blowers etc., However, heavy units such as leveller and cutter are to be balanced in their working position only. Before balancing them in their position, the knives are to be fixed first and the bearings are to be thoroughly cleaned. Then thin oil like DTE heavy medium is to be applied to the bearings so that there will not be any resistance when the shaft is rotated. Instead of oil if grease is applied the bearings may give some resistance. Then the bearing covers are to be closed. The unit may be moved by hand for one or two rounds to see whether there is any friction due to misalignment. The bearing pedestal covers may touch the shaft and produce some resistance. Make sure that the alignment of the bearings is perfect. The felt packing for bearing pedestals should not also be put while balancing the unit, as it may also produce some resistance.

Rotate the shaft by hand by one or two rounds and wait till it comes to rest. Mark a point on the flywheel with respect to the fixed point on the chute or body cover. Again rotate the flywheel and allow it to come to

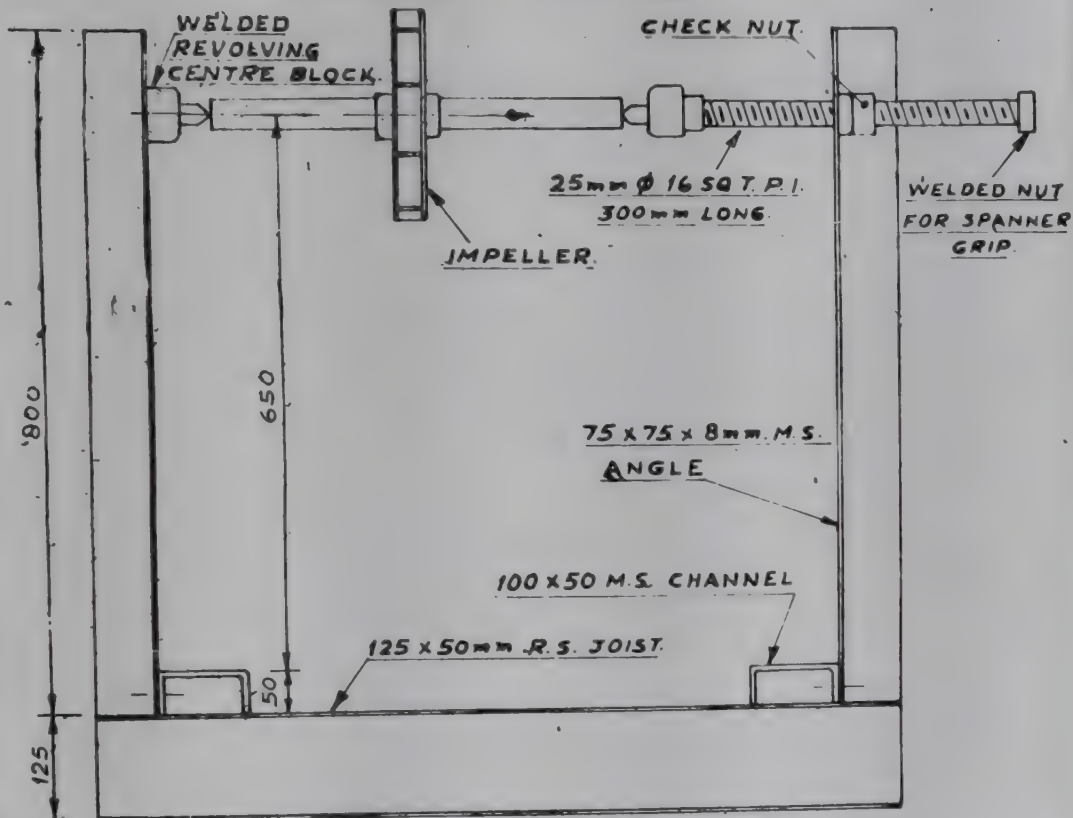
rest. Mark the position of the flywheel with respect to the fixed point on the chute. Similarly take a number of markings on the flywheel. The marking should evenly spread on the flywheel. Then we can say that the balancing of the unit is correct. If every time the flywheel comes to rest at the same point we can understand that the weight at the bottom is more and hence some liner plates etc., are to be provided to the top exactly opposite to it. The exercise may be repeated till the markings are got equally on the flywheel.

Now coming to our simple balancing device the impeller with shaft is to be fixed in the balancing machine as shown in the sketch. If the impeller is having more weight on one side, then that portion will always come to the bottom. A metal piece equal to the difference of weight may be tack welded to the impeller on its top portion exactly in the opposite direction. The procedure may be repeated till markings are got equally on the periphery of the impeller which shows that it is perfectly balanced.

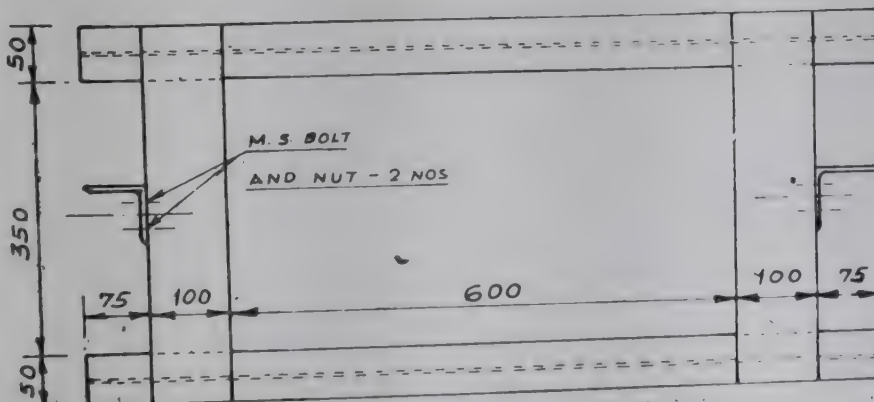
BALANCING MACHINE FOR CENTRIFUGAL PUMP IMPELLER

SCALE = NTS.

UNIT = mm.



ELEVATION



PLAN

USE OF ALUMINIUM TUBES IN SUGAR INDUSTRY RAW JUICE HEATERS

By

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Introduction

Over the last decade the Indian Sugar Industry has been in search of a less expensive metal to replace brass and copper tubes, without any chemical and mechanical complications, but with the same heattransfer rate in the heat exchangers. Some authors in the past, had suggested the use of steel tubes in juice heaters and other heat exchangers, but practice reveals that there are certain difficulties in the use of steel tubes—viz.

- (i) They corrode quickly and hence the life is only 2 to 3 years.
- (ii) There are difficulties in the cleaning these tubes as the surface becomes rough.
- (iii) The rate of heat-transfer is less than copper, brass, and aluminium as given in the table below.
- (iv) The scrap value of these is negligible.

Metal	Thermal Conductivity Cal/sq. cm/sec/°C.	Specific Gravity
1. Copper	0.941	8.98
2. Brass	0.290	8.53
3. Mild Steel	0.124	7.86
4. Aluminium	0.530	2.71

During the season 1970-71 we were to replace brass tubes of three juice heaters of 139.5 sq. m. heating surface each, costing nearly Rs. 1.5 lakhs. The authors then decided to 'repack' two juice heaters with aluminium tubes. The decision was taken because of the following benefits.

- (i) The cost was low, i. e. nearly 1/6 that of brass.
- (ii) It was a corrosion and rust proof metal like brass.
- (iii) The metal had no chemical reaction with cane juice.
- (iv) The heat transfer rate was better than that of brass as mentioned in the table above.
- (v) Its inertness maintains a smooth surface which allows easy cleaning as with brass and copper.
- (vi) The scrap value was 60% of the new tubes.

Description of the Heat Exchangers.

Raw Juice Heating

The factory is a Double Carbonation and Double Sulphitation plant of 1800 tonnes crushing capacity. It has three juice heaters for raw juice heating (equivalent to 139.5 sq. m. heating surface each). In addition, there is one vapour line juice heater of 186 sq. m. heating surface. Vapour line juice heater along with one juice heater is used at a time for heating the raw juice from 15/20°C to 55°C when vapour line juice heater is closed for cleaning, two juice heaters in series are

used for raw juice heating and one juice heater remains under cleaning.

Second Juice Heating

There are two juice heaters for heating the second carbonated juice from 50/52°C to 72°C of 93 sq. m. heating surface. Beyond this there is a plate type heat exchanger for preheating of juice which was replaced only two years back.

There are two sets of quads of total heating surface 3836.5 sq. m. and a vapour cell of 930 sq. m. heating surface for concentrating the thin juice. Hence it was decided that we should find out some less expensive replacement for the brass tubes of these heat exchanger without affecting the efficiency. It was thought that probably extruded aluminium tubes could be used as an alternative. Hence the matter was discussed with the technical staff of Indian Aluminium Company Limited, Calcutta at their office in New Delhi. After going through the chemical and mechanical properties of aluminium alloys, it was concluded that their alloy 50S-WP confirming to HE-9 WP of IS-1285 will be very suitable for replacing brass tubes. But the chemical properties clearly mention that alkaline medium, i. e. the presence of (OH) group corrodes aluminium faster. Hence the matter of replacing the brass tubes of quads was dropped because boiling caustic soda is used for cleaning quads. However, replacement of raw juice heater and pre-heater brass tubes was taken up and 42.4 mm OD × 14 SWG, 3938 mm (13 ft. 1 inch) long extruded aluminium tubes were procured from the above firm for both the juice heaters.

Observations**Raw Juice Heater****Pre-heater**

In the pre-juice heater, aluminium tubes started leaking within a month, from the expansion joints. Hence the heater was stopped, and after changing the leaky tubes, it was started again. But it was giving constant trouble throughout the season. Hence at the close of the season, this heater was repacked with brass tubes. With improved installation practices, this problem could possibly be overcome.

In raw juice heaters, these tubes are working very satisfactorily since 1970 and some observations are given below.

- (i) There is no cleaning trouble in these heaters. They are periodically cleaned every third or fourth day.
- (ii) Six years have passed and there is hardly any wear and tear in the tubes, as is clear from the table given below.

Sl. No. of aluminium tube from different passes.	Original weight of tubes (Kg.)	Weight of tubes after 6 years' use (Kg.)	Difference in Weight (Kg.)
1.	2.555	2.510	0.045
2.	2.550	2.510	0.040
3.	2.555	2.515	0.040
4.	2.556	2.478	0.077
5.	2.556	2.500	0.056
6.	2.550	2.456	0.094
7.	2.555	2.496	0.055

(Contd.)

Sl. No. of aluminium tube from different passes,	Original Weight of tubes (Kg.)	Weight of tubes after 6 years' use (Kg.)	Difference in weight (Kg.)
8.	2 555	2.510	0.040
9.	2.556	2.460	0.096
Average weight	2.554	2.494	0.060

From the above table it is clear that the loss in weight in each tube is only 50 gms to 100 gms. out of an original weight of 2.5 Kg. after using them for six years. The loss in weight comes to 4% max which is quite negligible.

- (ii) During the six years period of use, no colour etc. was imparted to the clear juice and juice was as brilliant in the case of brass tubes.
- (iv) There was no extra scaling problem in these juice heaters.
- (v) The cleaning period and the quality of cleaned tubes was found to be the same as that for brass.
- (vi) The scaling, rusting and pitting on outside of the tube, i.e. the steam side, was also found to be negligible.

(vii) These tubes once taken out from the heater could not be re-used like brass tubes, as they got damaged during the process of extraction. (*)

(viii) The cost of aluminium is less than half of brass for the same unit weight but the weight of aluminium tubes is less than 1/3 of the brass tubes.

(ix) The aluminium tubes were put in the heater like brass tubes after slightly annealing both the ends of the tubes and these were then expanded by tube expander as for brass. Of course, the pressure applied was not equivalent to that of brass considering the lower hardness of aluminium. After the expansion, the heater was tested at 40-50 psi pressure as usual in case of brass.

* With controlled expansion while packing, this problem can possibly be overcome.

Conclusion

After using the raw juice heaters with aluminium tubes for six years, it is now definite that aluminium tube is a better replacement for brass tubes, without any loss of efficiency in raw juice heaters. The authors are further trying extruded aluminium tubes Properly anodised, in pans of A, B and C rnassecuities. The observation will be submitted after the season 1977-78. We hope these will also be able to replace the Pan brass tubes with same results as that of brass thereby solving great problem of the sugar Industry.

Acknowledgments

The authors are extremely grateful to the Managing Directors Lala Hari Raj Swarupji, Lal Gopal Raj Swarupji and Lala Brahma Swarupji of Sir Shadilal Sugar & General Mills, Mansurpur, for their kind permission and interest to carry out the proposed changes and to publish the results thereof. The authors are very much thankful to Indian Aluminium Company Limited who took interest in conducting these experiments usefully and successfully.

INSTALATION OF RESISTANCE HEATER

By

A, P. Chinnaswamy, R. Lokan and R. Venugopal

Directorate of Sugar, Madras.

The cooled Low Grade massecuite is to be reheated to 55°C to reduce its viscosity which brings about good purging with the resultant good quality C-For sugar. The overall benefit is in the increase of pan capacity and reduction of process losses due to elimination of recirculation of non sugars.

The reheating is usually done with the help of hot water in the crystallisers or pugmill. Using of third body vapour as the heating medium in the pugmills has also been advocated.

With these systems of reheating there is always the danger of redissolution of sugar in molasses. Even when the temperature of hot water is maintained constant by the use of thermostat control, the redissolution of crystals takes place increasing the losses in Final Molasses.

This draw back can be eliminated by the use of R. H for reheating. It is very simple and easy to operate. The advantages of R. H. are :

1. Decreased losses in Final Molasses due to very short retention time at high temperatures.

2. Increased purity of C. F. Sugar and decrease in recirculation of non sugars.

3. Saving in crystalliser or availability of more time for maturity of the massecuite.

4. Negligible maintenance as there are no moving parts.

5. Easier and effective temperature control.

6. Simplicity in construction.

7. Increase in the capacity of centrifugals as the purging quality is increased when the massecuite is heated to a little more than the redissolution.

A successful design suitable for our factories was designed by Ramaiah and Gupta of National Sugar Institute¹. This is rectangular in shape with plate type electrodes.

This can be operated on 440 or 220 volts as the case may be.

The heating is done by the three layers of electrodes. Ramaiah and Gupta recommended a head of 1 to 1.5 m. for easy flow of massecuite.

Power Required³

$$P = 0.012 Q (t - t_0) \text{ where}$$

P = Power required in K.W.

Q = Quantity of massecuite flow in cu. ft./hr.

t_0 = Temperature of massecuite before heating °F

t = Temperature of massecuite after heating °F

The power required for raising the temperature of the massecuite by 27°F for various capacities are given below :

T. C. D.	C-massecuite cu.ft/hr	Power required (KW)
1500	170	55
2000	225	73
2500	285	92
3000	340	110
4000	450	146

(Temperature of massecuite before heating $t_0 = 131^\circ\text{F}$)

Temperature of massecuite after heating $t = 104^\circ\text{F}$)

C — massecuite % cane ... = 10%

Hours of curing per day ... = 22

The power required is only 3.0% of the total power generated. All most all the factories should be able to afford this increase in power.

Cost of unit :

The cost of Resistance Heater for 2500 TCD factory with batch machines may be around Rs. 20,000/-. For continuous machines a R. H. of 2.5 t/hr. capacity may cost about Rs. 5,000/-.

This is cheaper when compared with the cost of a heating crystalliser, water pump, water tank with temperature control system etc.

Also the maintenance cost will be negligible compared to conventional heating system.

Economics⁴

If R. H. is installed in place of conventio-

nal heaters, the rise in purity of Final Molasses due to dissolution of crystals will be .10 to .5 only compared to 1.0 to 1.5 unit of crystalliser heated massecuite. A minimum purity difference of 0.5 can be expected between the two systems of heating which gives an increase in recovery by 0.02 unit.

For a crush of 2.5 lakh tonnes per season the extra sugar bagged will be 500 qtls. At the rate of Rs. 225 per qtls. increase in profit is Rs. 1,12,500 per season. This more than justifies its installation.

Installation of Resistance Heaters :

Resistance heaters can conveniently be installed for any type of lay out wheather it be gravity type, semi gravity type or non gravity type.

It can also be installed for use with continuous centrifugals or with batch centrifugals.

It is much easier to install it if careful planning is done when factories expand their capacities,

Installations for the following lay outs are discussed.

I. Semi gravity type :

(a) Salem Cooperative Sugar Mills Ltd.—Continuous Machine.

(b) Kallakurichi Cooperative Sugar Mills—Batch Machines.

II. Gravity Type :

(a) Madurantakam Cooperative Sugar Mills Ltd.—Batch Machines.

(b) Dharmapuri District Cooperative Sugar Mills—Batch Machines.

III. Non-Gravity Type :

(a) Ambur Cooperative Sugar Mills Ltd.—Batch Machines.

(b) Amaravathi Cooperative Sugar Mills Ltd.—Batch Machines.

I. Semi Cravity Type :

(a) Salem Cooperative sugar Mills — Continuous Machines (Fig. 1)

This was originally a Non-Gravity type plant with batch machines and continuous crystallisers.

When the capacity was expauded from 1750 to 2500 TCD it was converted to Semi-Gravity type with continuous machines for C-fore working by placing the continuous crystallisers above the centrifugals.

Individual R. H. was installed for each continuous centrifugal. With this arrangement the problem was the flow of cooled massecuite at 40°C through the grills of pugmill.

To overcome this problem it is now proposed to install a R. H. after the last crystalliser and to heat the C Massecuite to 45 — 48 C to enable to flow easily through the pugmill grills.

(b) Kallakurichi Cooperative Sugar Mills Ltd. — Batch Machines (Fig. 2)

When Kallakurichi Cooperative Sugar Mills Ltd. was expanded from 1000 to 2000

t.c.d. the non-gravity batch type C-Crystallisers were converted to Semi-Gravity Continuous Crystallisers.

Two nos. of R. H. were placed above the two pugmills of the batch C-fore workers. The overflow of the cooled massecuite is taken by a channel to the R. H. The heated massecuite is directly discharged into the pugmills.

Case II. Gravity Type :

(a) **The Madurantakam Cooperative Sugar Mills Ltd.**—expanded its capacity from 1000 t.c.d. to 1750 t.c.d. This is a Gravity Type plant with batch machines for C-fore working.

The batch crystallisers were converted into continuous crystallisers, (Fig. 3)

The Resistance Heater is kept above the pugmill. The cooled massecuite is taken to it from the overflow of last crystalliser and after heating is discharged directly into the pugmill.

(b) **Dharmapuri District Cooperative Sugar Mills Ltd.**—is a 1250 t.c.d. plant of Gravity type. It is proposed to convert the 5 batch crystallisers into continuous ones by the addition of two more crystallisers to work as receivers. With the help of a massecuite will be pumped into the continuous cooling crystallisers. The overflow of the last crystallisers will be heated by the Resistance Heater above the pugmill. (Fig. 4)

Case III. Non-Gravity Type :

(a) **The Ambur Cooperative Sugar Mills Ltd.**—is a non gravity type factory with cooling crystallisers on the ground floor.

The crystallisers were first made continuous by installing 2 air cooled receivers and interconnecting the water cooled crystallisers. The Resistance Heaters were placed adjacent to the last crystalliser. The cold massecuite overflow is taken into the Resistance Heater through a feed hopper. After heating to 55°C it is discharged into a channel and pumped to the pugmill of C-fore workers. (Fig 5)

(b) **The Amaravathi Cooperative Sugar Mills Ltd.**—was having 10 water cooled crystallisers for C-side. This was made continuous with 2 receivers and 2 batches of continuous crystallisers with 4 crystallisers in each. Here also the crystallisers were placed in descending steps.

Resistance Heaters are being installed adjacent to the last crystallisers of both batteries. The heated massecuite is then pumped to the pug mills.

Conclusion :

From the above it can be seen Resistance Heater can be installed in any type of lay out, Gravity, Non-Gravity or Semi-Gravity. If necessary slope and head are provided for the flow of cold massecuite to the R. H smooth working will be automatically ensured. The rectangular resistance heater of Ramaian and Gupta is a boon to the sugar industry and all our factories should take advantage of it by installing the same at the earliest.

Acknowledgement

We thank the Director of Sugar Thiru V. Lakshmi Ratan, I. A. S. for his keen interest and encouragement.

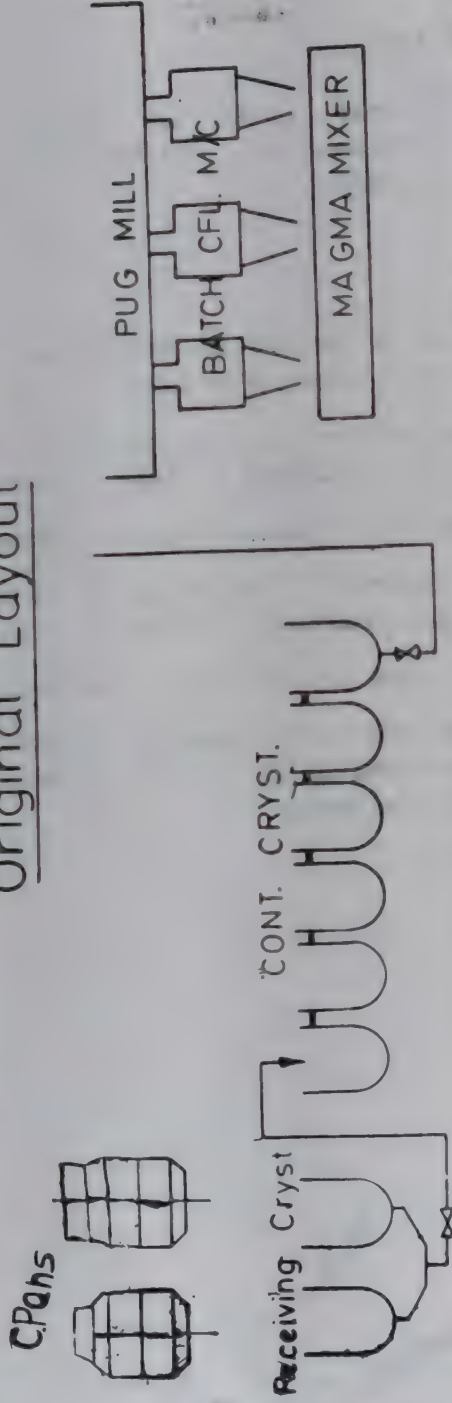
Our thanks are also due to Dr. N. A. Ramaiah and H. N. Gupta of National Sugar Institute for their advice and assistance in the installation of the resistance heaters in our factories. Thanks are also due to Mr. Krishnamoorthy, TASCO, Madras for the drawings.

Reference

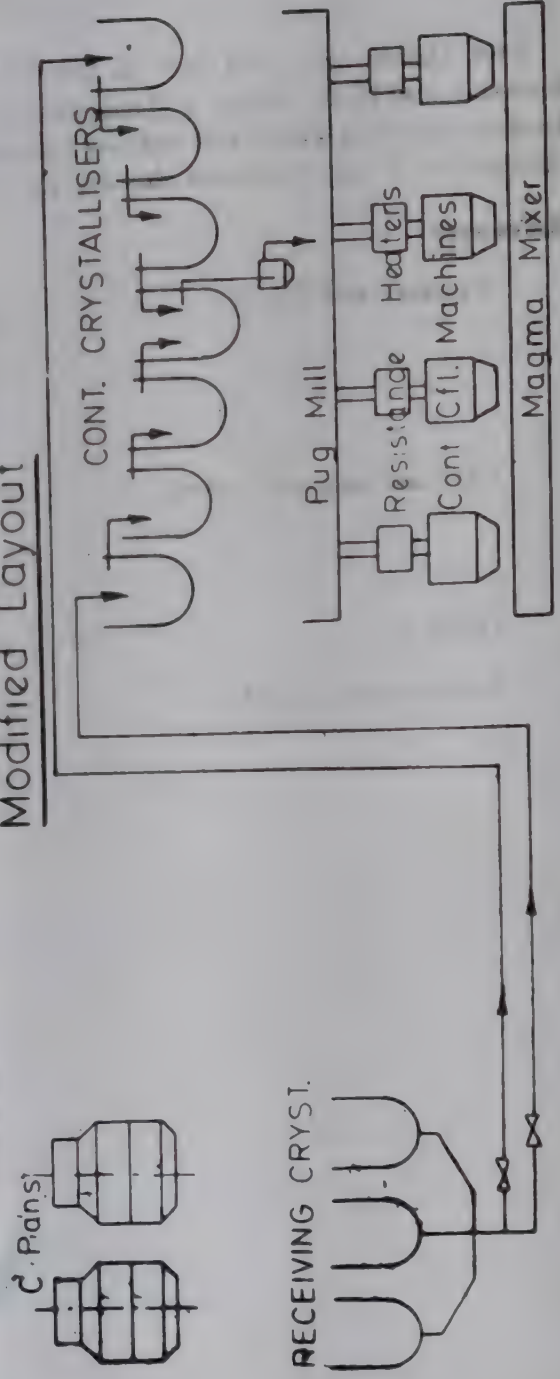
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| Ramaiah and Gupta | — | Results on the use of Rectangular Resistance Heater for heating Masecuits |
| | | — Proceedings of Seminar on use of continuous centrifugal machines in Sugar factories-P. 55-57 |
| Chinnaswamy and Lokan | — | Centrifugal Accessories-Resistance Heater |
| | | — Proceedings of Seminar on use of continuous centrifugal machines in Sugar Factories-P. 48-54 |
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| Ramaiah and Gupta | — | A new Design of Rectangular Resistance Heater for reheating of Low Grade masecuite - 16th ISSCT Proceeding. |

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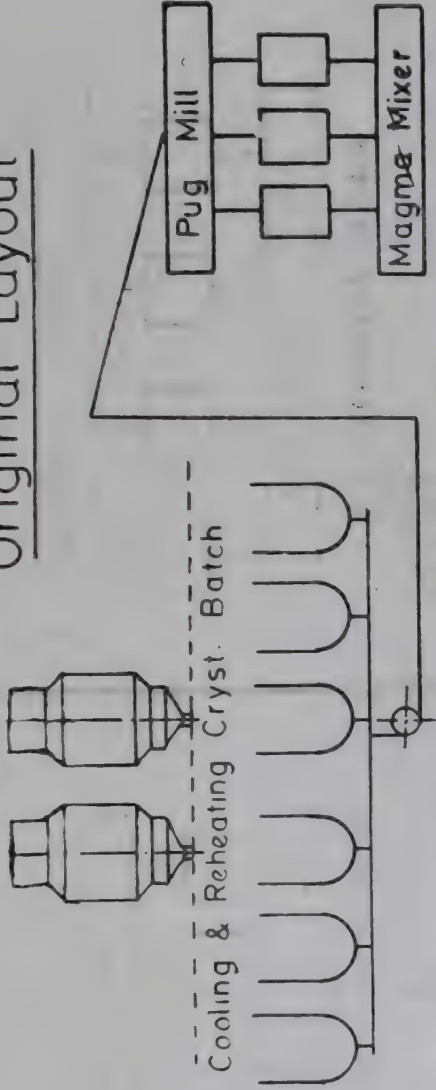


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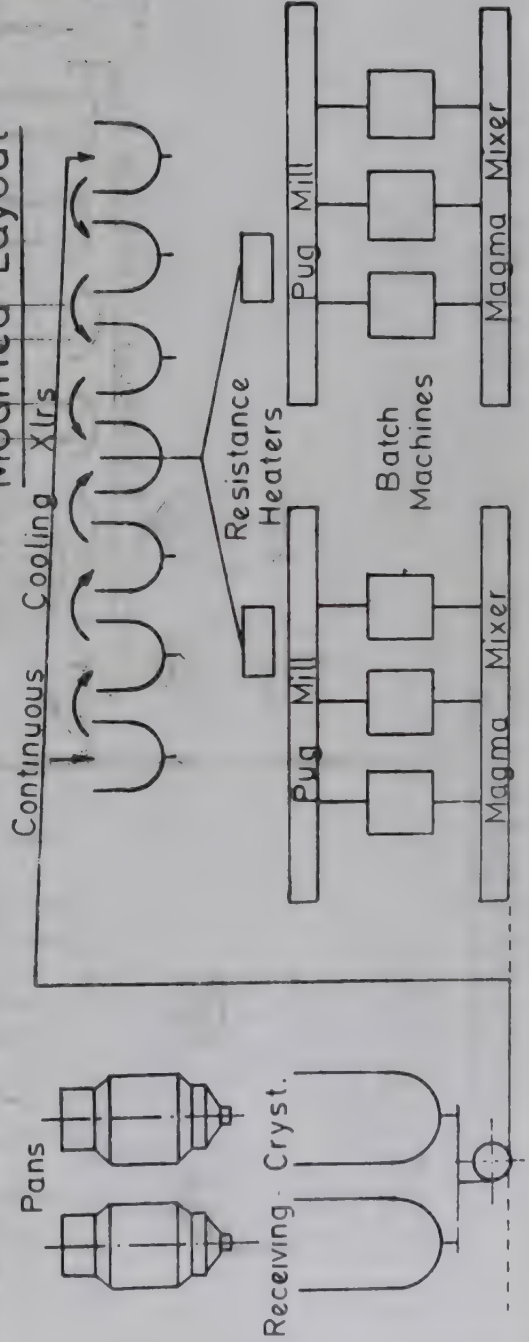


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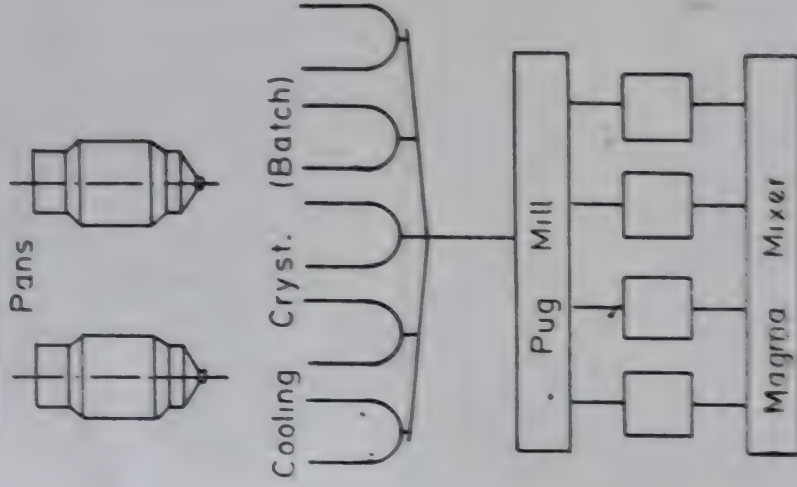


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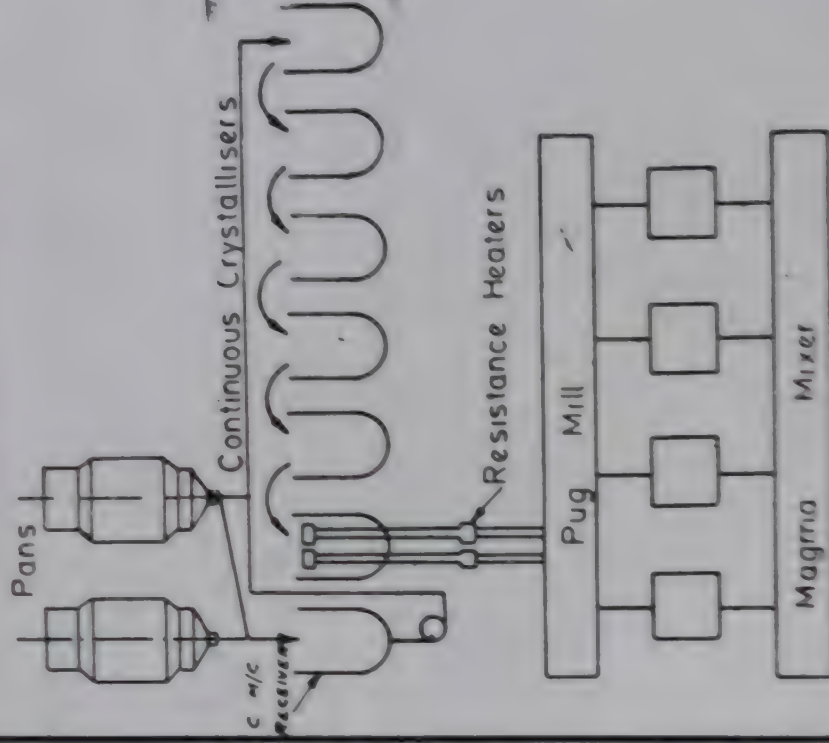


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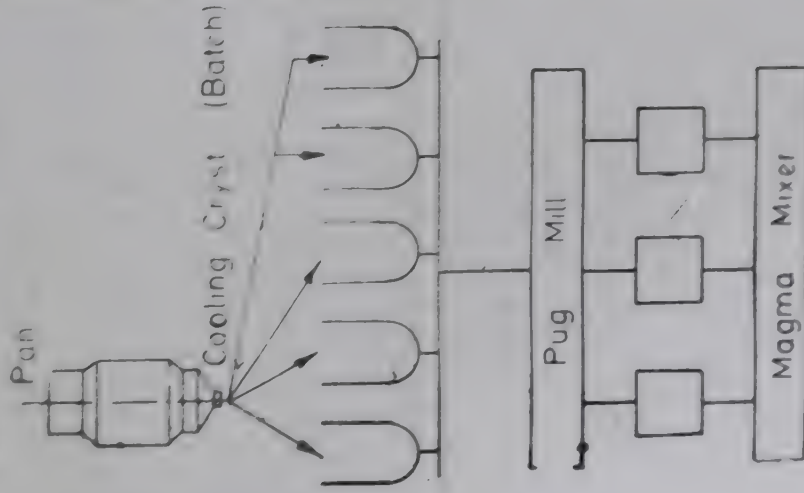


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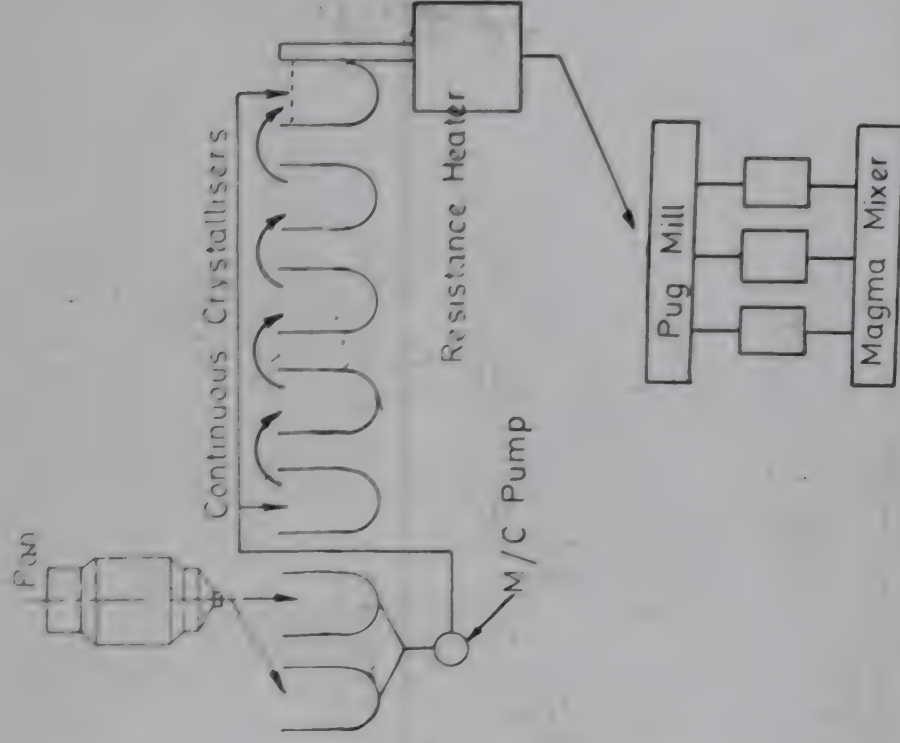


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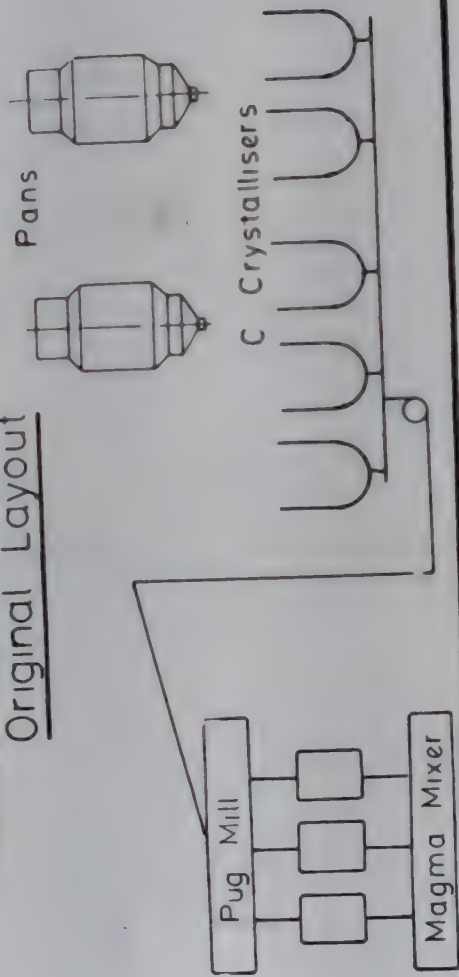


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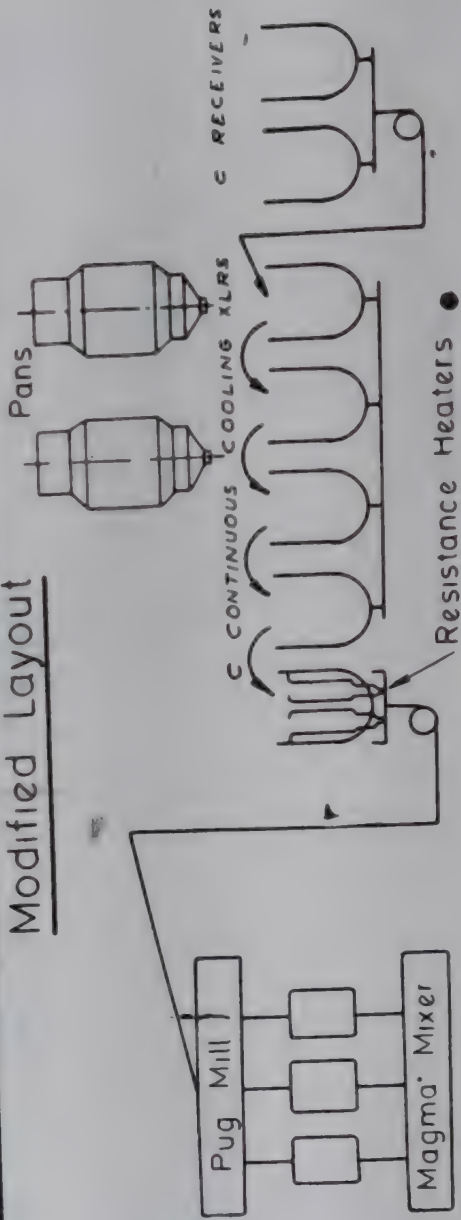


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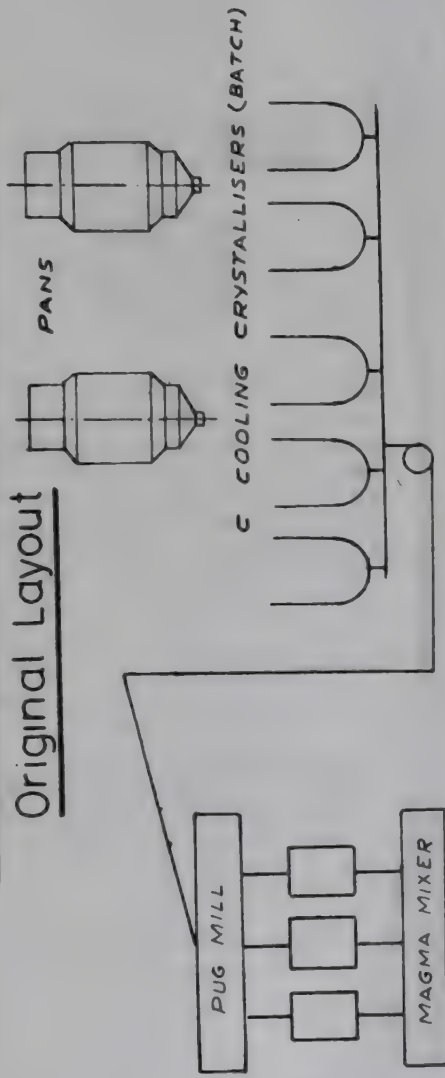


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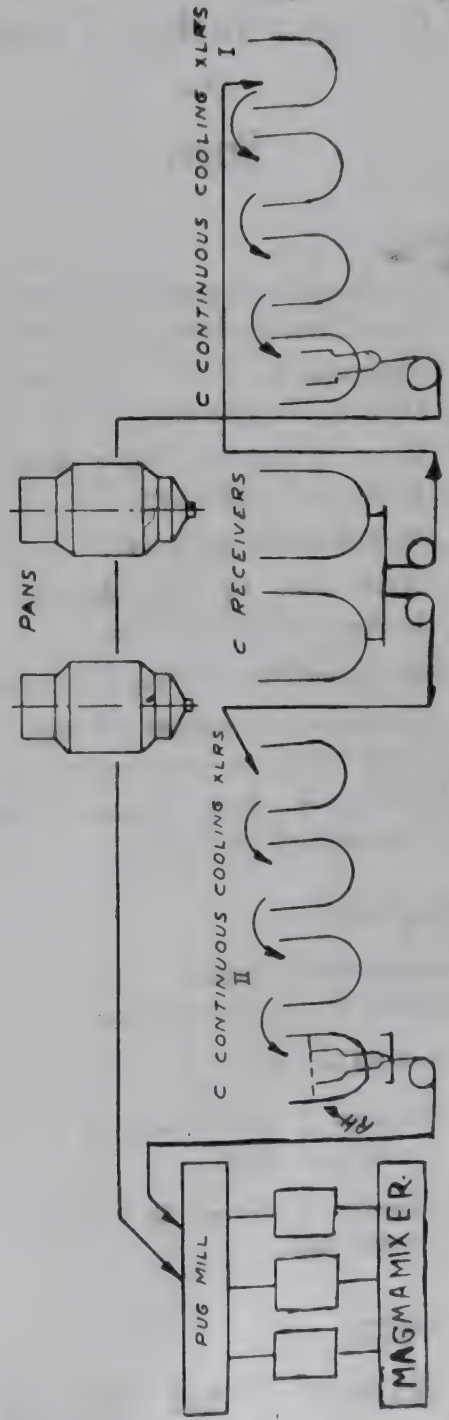


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FACTORY PERFORMANCE INDEX (F. P. I.)

By

R. Lokan and A. P. Chinnaswamy

Directorate of Sugar, Madras

ABSTRACT

A new formula is proposed to judge instantly the performance of a sugar factory. This formula takes into account all the relevant factors like crushing, milling and boiling house efficiencies.

Introduction

The technical efficiency of sugar factories is usually judged by their efficiencies in the mill and the boiling house extractions or by the overall extraction which is a combination of both. The rate of crushing is analysed separately. Many a time it is difficult to come to a conclusion about the overall performance of the factory because due to high rate of crushing, efficiencies are affected or efficiency will be higher at a lower rate of crush. For example, if a factory's rated capacity is 2000 TCD and it is crushing 2500 TCD, the efficiency in the mills may be little affected, but in the boiling house due to overloading, the clarification may not be good, loss in the filter station may increase and above all loss in F. M. may increase due to improper

exhaustion. Due to these the boiling house efficiency may decrease.

On the contrary, in the case of low rate of crush the efficiencies in the boiling house will increase. The vacuum filter can rotate at lower speed recovering more sugar from mud and the massecuites can be cooled and matured for a sufficiently long time, thus increasing the exhaustion. Even though the efficiency is higher the overall performance of the factory will be poor due to low crushing.

So as to enable one to judge a factory instantly and correctly, a formula was thought of. In South Africa there is this formula F. P. I., but in spite of a lot of efforts, we could not get any details about this F. P. I. or how it is calculated.

So, keeping the same nomenclature F. P. I. a new formula was worked out combining both crushing rate and efficiencies as enumerated below.

In the new formula both the capacity and efficiencies are interlinked. For the efficiency the 'overall extraction' is taken. This will represent the efficiency of the entire plant. It is further advantageous to take 'Reduced overall Extraction' so that the factory can be compared to any other factory or for any

other season. The formula is simply a ratio of actual and ideal figures.

To judge anything it is always customary and advantageous to take 100 as the base index.

Accordingly here also it is assumed that 100 index will be the ideal.

The base index 100 is to be divided between capacity and efficiency. To give more weightage for efficiency it is better to take the ratio of capacity : Efficiency as 40:60.

$$\text{FACTORY PERFORMANCE INDEX} = 40 \times \frac{\text{Actual capacity}}{\text{Installed capacity}} + 60 \times \frac{\text{Actual R. O. E.}}{\text{Ideal R. O. E.}}$$

The ideal R. O. E. for 12 roller tandem is taken as 85.54 based on standard norms.

$$\begin{aligned} \text{The norm for ideal RME} &= 94 \text{ (12 roller tandem)} \\ &= 95 \text{ (18 roller tandem)} \end{aligned}$$

$$\text{The norm for ideal RBHR} = 91$$

$$\therefore \text{Ideal R. O. E. for 12 roller tandem} = \frac{94 \times 91}{100} = 85.54$$

$$\begin{aligned} \text{Same way ideal R.O.E. for 18 roller tandem} &= \frac{95 \times 91}{100} = 86.45 \end{aligned}$$

The installed capacity of the factory is well known. The actual capacity is arrived at as follows : For any day, it is the actual cane that is crushed. For the run or month or the season it is better to take the cane crushed per 24 season hours. This is arrived at by dividing the total quantity of cane

crushed by total available hours and multiplying it by 24.

The advantage of taking the average cane crushed per 24 season hours is that it takes care of Time lost,

Rate of crush and Duration of the season,

Examples**I. Factory Performance Index For The day**

Suppose a factory with a 18 roller tandem crushed for the particular day to the installed capacity of 2000 M. T. and obtained a R. O. E. of 86.45.

$$\begin{aligned} \text{F. P. I.} &= 40 \times \frac{2000}{2000} + 60 \times \frac{86.45}{86.45} \\ &= 100 \text{ Satisfactory} \end{aligned}$$

Supposing the next day cane crushed was 2300 Tonnes and the R. O. E. achieved was 86.00

$$\begin{aligned} \text{Now F. P. I.} &= 40 \times \frac{2300}{2000} + 60 \times \frac{86.00}{86.45} \\ &= 46 + 59.68 \\ &= 105.68 \\ &= 106 \quad \text{GOOD} \end{aligned}$$

In this case even though the efficiency is less overall performance is very satisfactory.

Suppose the crushing is 1950 and R. O. E. achieved is 87.00 then :—

$$\begin{aligned} \text{F. P. I.} &= 40 \times \frac{1750}{2000} + 60 \times \frac{86.00}{86.45} \\ &= 35 + 60.38 = 95.38 \\ &= 95 \text{ AVERAGE} \end{aligned}$$

In this case eventhough the efficiency is higher, the overall performance is NOT SATISFACTORY.

II. Factory Performance Index For The Month

Factory A (12 roller tandem)

$$\text{Rated capacity} = 1250 \text{ TCD}$$

Cane crushed for the month = 37002 Tonnes

Total available hours = 672-00

∴ Cane crushed per 24 season hours = 1321 Tonnes.

Reduced Mill Extraction = 93.45

Reduced Boiling House Extraction = 90.48

R. O. E. ... = 84.66

$$\begin{aligned}
 \text{F. P. I.} &= 40 \times \frac{1321}{1250} + 60 \times \frac{84.66}{85.54} \\
 &= 42.27 + 59.38 \\
 &= 101.65 \\
 &= 102
 \end{aligned}$$

Performance of the factory can be considered as very satisfactory.

Factory-B (18 roller tandem)

Rated capacity = 1750 TCD

Cane crushed for the month = 43847 M. T.

Total available hours = 672

∴ Cane crushed for 24 season hours = 1566 M. T.

R. M. E. = 95.77

R. B. H. R. = 89.99

R. O. E. = 86.18

$$\begin{aligned}
 \therefore \text{F. P. I.} &= 40 \times \frac{1566}{1750} + 60 \times \frac{86.18}{86.45} \\
 &= 35.66 + 59.81 \\
 &= 95.47 \\
 &= 95
 \end{aligned}$$

Performance of factory B is not satisfactory.

Factory-C (12 roller tandem)

Rated capacity = 1250 TCD

Cane crushed for the month = 33886 M. T.

Cane crushed/24 season hours = 1210 M. T.

R. M. E = 94.10

RBHR = 91.49

R. O. E. = 86.09

$$\therefore \text{F. P. I.} = 40 \times \frac{1210}{1250} + 50 \times \frac{86.35}{85.54}$$

= 38.72 + 60.35

= 99.07

= 99 Satisfactory.

III. Factory Performance Index For The Season

Factory -D (12 roller tandem)

Rated capacity = 1250 TCD

Cane crushed for 1976-77 season = 218006 M. T.

Cane crushed/24 season hours = 1192 M. T.

R. M. E. = 92.30

R. B. H. R. = 90.75

R. O. E. = 83.76

$$\begin{aligned}
 \text{F. P. I.} &= 40 \times \frac{1192}{1250} + 60 \times \frac{83.76}{85.54} \\
 &= 38.14 + 58.75 \\
 &= 96.89 \\
 &= 97
 \end{aligned}$$

Performance is satisfactory.

Factory-E

$$\text{Rated capacity} = 1000 \text{ TCD}$$

(This is a 18 roller tandem. As the expansion in boiling house was incomplete it was crushing at 1000 TCD. The extra capacity in the boiling also could not be utilised for want of power).

$$\text{Cane crushed} = 121616.099 \text{ M. T.}$$

$$\text{Cane crushed/24 season hours} = 1082 \text{ M. T.}$$

$$\text{R. M. E.} = 95.72$$

$$\text{R. B. H. R.} = 90.80$$

$$\text{R. C. E.} = 86.91$$

$$\begin{aligned}
 \text{F. P. I.} &= 40 \times \frac{1082}{1000} + 60 \times \frac{86.91}{86.45} \\
 &= 43.28 + 60.32 \\
 &= 103.60 \\
 &= 104 \quad \text{Very satisfactory}
 \end{aligned}$$

Discussions

The above examples give an idea about the factory performances as a whole. By calculating the F. P. I. one can easily judge the entire factory performance and can plan

improvements. It is better to indicate F.P.I. in round No. for ready reference as accurate figures and decimals are not so essential.

To achieve the installed capacity for the season the factory has to work a little above

the rated capacity and stoppages should be minimum. At this increased rate of crush the efficiencies are also to be taken care of.

If any factory obtains F. P. I. 100 and above it is a very good achievement. If it is between 95 and 100, we can take it as satisfactory. Below 95 the performance is average. And below 90 it is very very poor.

Conclusion

F. P. I. should be included in the routine control figures of every sugar factory for judging the performance of the factory and for taking remedial measures.

Acknowledgements

Our Thanks are due to Thiru V. LAKSHMI RATAN, IAS, DIRECTOR OF SUGAR, TAMIL NADU for permission to publish this paper.

A STUDY OF DROP IN PURITY IN THE BOILING HOUSE

By

N. R. Tagore

Challapalli Sugars Ltd., Lakshmipuram Dist. Krishna (A. P.)

ABSTRACT

During the clarification of Juice, drop in purity observed in Juice heaters, clarifier and Vapour cell may create confusion in pol balance as unknown loss increases. In this article drop in purity is discussed at various units and measures taken to control the same.

The maximum yield and quality of Sugar depends upon the clarification in the boiling house. During the process stage drop in purity depends upon the factors when juice in :—

1. Juice heaters when subjected to high temperature and lower pH of juice:
2. Clarifier due to longer retention time and,
3. High pressure boiling at Vapour cell.

When drop in purity observed in the process, it creates confusion in the Pol balance as the apparent purity of Syrup is less than that of Mixed juice.

The drop in purity is observed in the following stages from

- i. Mixed Juice to clear juice and drop in purity to the order of 0.5 to 1.2 units.

- ii. Clear juice to unsulphured syrup to the order of 0.8 to 1.3 units.

1. Mixed Juice to Clear Juice

The drop in purity is first suspected in the clarifier. On checking the retention time of juice is only 3 hrs 15 mts only which is quite normal. Further on investigation it is found that drop in purity when

- i. The temperature is maintained between 60°C-70°C
- ii. The temperature of treated juice is maintained between 100°C-110°C
- iii. pH of the treated juice maintained between 7.0 - 7.2

In clarification as pH and temperature play a key role the following precautions are taken

- i. The temperature of raw juice is maintained between 55°C to 60°C.
- ii. The temperature of treated juice is maintained between 96°C to 98°C.
- iii. pH of the Treated at 7.3

Care is taken that the treated juice should never be heated above 100°C as there may be destruction of reducing sugars and colour formation due to high pH and temperature. Further at clarifiers the maintenance of higher

temperature above 100°C if flashing is allowed the settling may not be fast due to rise in Brix from mixed juice to clear juice and occlusion of vapours in the juice inspite of best flash releasing equipment. After taking the above precautions the drop in purity is under control when the treated juice pH ranges between 7.2 to 7.3 which can be observed from the final results in Table No. 1 below. The clear juice at pH 7.1 is of good quality and no colour formation of juice due to controlled temperature of treated juice.

Table—1

Trial	Purity of Mixed Juice	pH of Treated Juice	Purity of Clear Juice	pH of Clear Juice
1.	81.75	7.0	81.32	6.8
2.	81.96	7.1	81.71	6.9
3.	82.01	7.2	82.10	7.0
4.	82.25	7.3	82.40	7.1

2. Clarifier

The continuous clarifier will give improved clarification which means better performance in the boiling house and good quality sugar. The clarified juice is drawn from each compartments by pipes connected to the zone, where the juice is more clear. Only clear juice is discharged in to juice over flow box.

In continuous clarifier, it is opined that retention time should be about $2\frac{1}{2}$ hours and

if the retention time exceeds $3\frac{1}{2}$ hours it would bring about large drop in purity and pH.

In some factories even there is excess capacity of clarifier the juice is taken by overflow which brings considerable drop in purity due to longer retention time and some factories liquidate the juice from the required compartments to avoid more retention time. Continuous liquidation of clarifier is *not desirable* as the juice is hazy and contain bagacillo particles which effects the quality of sugar.

To avoid drop in purity in the excess capacity of the clarifier and hazy juice due to liquidation, an alternate method of overflow from clarifier is suggested below to avoid drop in purity and maintain good quality of sugar.

For example, a factory having excess capacity of clarifier with four compartments where only three compartments required for its scheduled capacity. Instead of liquidating the clarifier the alternate method of overflow of juice from place above the delivery point and below overflow level is advisable. By this, the juice will have sufficient setting time, it will be clearer than liquidation and stagnation of juice is avoided. The actual arrangement of tapping the juice from the pipes is shown in the figure No. 1.

3. Clear juice to unsulphured syrup

Now-a-days vapour cell has become very popular as it is an asset to the boiling house.

Vapour cell supplements the capacity of evaporator and compensates insufficient exhaust steam to the demand of the boiling house. Drop in purity is noticed in the Vapour cell when the exhaust steam pressure is above 6 lbs/sq. in. and clear juice pH below 7.0. It is well known fact that clear juice above 7 pH when subjected to high temperature there will be colour formation and destruction of reducing sugars which will ultimately effect the colour of the final product. Clear juice below pH 6.9 boiled at higher temperature in vapour cell causes drop in purity due to inversion.

To prevent high temperature, the exhaust steam at vapour cell is limited to 3-4 lbs/sq. in. and at quadruple 4.5 lbs/Sq. in. and pH of clear juice is maintained between 7.0 to 7.1 pH, on keeping clear juice pH slightly above 7.0 the drop in purity was in control which can be noted from the final results from table No. 2.

Table -2

Trial No.	pH of Clear Juice	Purity of Clear Juice	Purity of Unsulphited Syrup
1.	7.0	82.20	81.85
2.	7.0	82.40	82.42
3.	7.1	82.66	82.88

Acknowledgements

Permission of Sri S. R. Y. Ankeneedu Prasad and S. R. Y. Padmanabha Prasad, Managing Directors and Sri A. V. Chalapathi Rao, Plant Manager to publish this article are gratefully acknowledged.

The above study was carried at.

1. Mixed juice to clear Juice, Challapalli Sugars Ltd., Laxmipuram.
2. Clarifier.
V. V. S. Sugars Ltd., Chagallu.
3. Clear Juice to unsulphited Syrup.
The Kirlampudi Sugar Mills Ltd., Pithapuram.

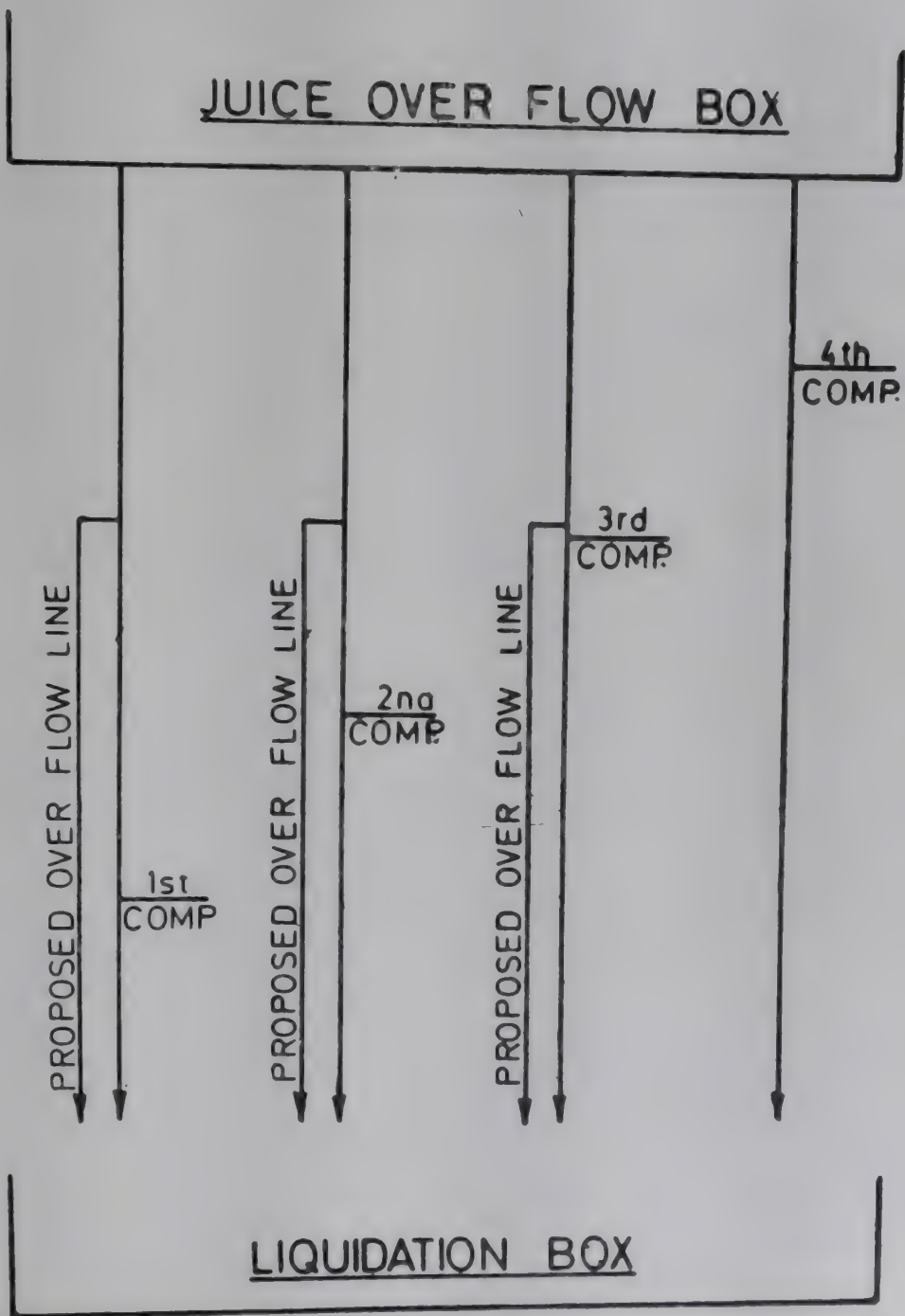


Fig. 1

UTILIZATION OF TF-S₃ AS A CLARIFYING AGENT IN GUR INDUSTRY

By

S. R. Mukharjee, R. D. Shahi and B. P. Sahi

Sugarcane Research Institute, Pusa (Bihar)

ABSTRACT

Studies on the efficiency of TF-S₃ (manufactured within the country) as a clarifying agent in gur industry revealed that its 0.1% solution was as good as Separan AP 30 (imported) at the same concentration. Extract of the petiole of piper betle, however, proved to be an inferior clarifying agent.

Introduction

Role of clarifying agents in open pan boiling sugarcane juice is well known for producing quality gur. Investigations in this direction have been carried out since last several decades using a large number of electrolytes and suitable proteinrich materials of vegetable origin, either alone or in combination. Khanna and Chacravarti (1955) discussed this topic exhaustively in a scientific monograph on gur. The results obtained indicate that some of the flocculating agents are more efficient than the others. The search for more suitable and better flocculating agents is still going on keeping in view the scope and importance of gur industry in the country.

0.5 % solution of lac resin to be as effective as standard groundnut extract for the production of quality gur. Similarly, 0.1% solution of Separan AP30 (an imported polyelectrolyte) in combination with lime and S. S. P. has been found to be an efficient clarifying agent at Sugarcane Research Institute, Pusa, during (1973-75.)

M/s. True Food Corporation, Jalgaon, Maharashtra (India) claimed that its product (TF-S₃) has an efficient flocculating power. But its utility was not tested in gur industry. Hence the objective of this investigation was to assess the efficiency of TF-S₃ as a clarifying agent for gur industry keeping Separan AP 30 as standard. Extract of the petiole of piper betle as also included in this study.

Recently Mukherjee *et al.* (1976) found

Materials and Methods

The experiment was carried out for three consecutive years at Sugarcane Research Institute, Pusa with the following treatments :

T₁ Control

T₂ Sugarcane juice + 5 gms lime/litre + 15 gms S. S. P./litre + 10 cc of 0.1% solution of TF-S₃/litre

T₃ Sugarcane juice + 5 gmslime/litre + 15 gms S. S. P./litre + 15 cc of 0.1% solution of TF-S₃/litre

T₄ Sugarcane juice + 5 gms lime/litre + 15 gms S. S. P./litre + 10 cc of 0.1% solution of Separan AP30/litre

T Sugarcane juice + 100 cc of 10 % extract of the petiole of piper betle/litre

Each treatment was replicated four times. Sugarcane variety used for gur making was B. O. 17.

Separan AP 30 was obtained from M/s. Dow Chemical International Inc., U. S. A. TF S₃ was obtained from M/s. True Food Corporation, Jalgaon, Maharashtra State (India).

The attributes of sugarcane juice determined were Brix, pol, purity and colour and those for gur were Brix, pol, purity, glucose, colour intensity, ash and total colloids by standard methods as prescribed by Khaana and Chacravarti (1955).

Results and Discussion

The data on the effect of clarifying agents on sugarcane juice are recorded in table 1.

A perusal of the data revealed that the brix, pol and purity of juice remained unaffected by the treatments. This suggested that sugar content in the juice remained intact. TF-S₃ and Separan AP 30, being at par, brought about desired improvement in juice quality by lowering its colour intensity. Extract of the petiole of piper betle, though superior over control, was found to be significantly inferior as compared to the above two electrolytes in this respect.

The data on Brix, pol, purity and glucose of the products (gur) are recorded in table 2. The above attributes of gur remained unaffected by the treatments indicating no deterioration in the sugar content of the gur.

The colour value, ash percentage and total colloid contents of the products (gur) are recorded in table 3. A light coloured gur is preferred to a dark product. Hence a lower value of colour intensity is desirable. The products of TF S₃ and Separan AP 30 showed significantly lower colour intensities as compared to control and piper betle extract. Low ash is desirable from the point of view of taste and keeping quality. The products of TF-S₃ and Separan AP 30 contained similar amounts of ash which were again significantly lower than the products of control and piper betle extract. Lower the total colloid content, the better is the quality of gur. Judging from this point of view, the two electrolytes (TF-S₃ and Separan AP 30), being at par, were again significantly superior as compared to control and piper betle extract.

Thus, at equal concentration (0.1% solution) TF-S₃ was as effective as Separan AP 30 for the manufacture of quality gur.

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Table 1
Effect of clarifying agents on the quality of sugarcane juice

Treatment no.	Br ix			Pol %			Purity %			Color Value		
	1974-75	1975-76	1976-77	1974-75	1975-76	1976-77	1974-75	1975-76	1976-77	1974-75	1975-76	1976-77
T ₁	19.4	19.2	22.8	17.0	16.8	19.7	87.8	87.7	86.5	200.2	198.1	171.2
T ₂	20.8	19.5	23.0	17.8	17.2	19.8	88.0	88.0	86.7	49.7	47.1	67.1
T ₃	20.5	19.5	23.0	17.7	17.1	19.9	88.0	87.8	86.6	55.6	47.3	67.8
T ₄	20.6	19.4	23.0	18.1	17.0	19.9	87.8	87.6	87.0	50.0	47.8	67.1
T ₅	19.7	19.5	22.7	17.3	17.0	19.5	87.6	87.5	86.3	101.0	183.3	155.0
S. E. (Tr) Mean	0.82	0.24	0.18	0.80	0.30	0.47	1.15	1.36	1.67	1.45	4.47	3.07
C.D. at 5%	—	—	—	—	—	—	—	—	—	4.47	13.77	9.46
C.D. at 1%	—	—	—	—	—	—	—	—	—	6.26	19.31	—

Table-2

[illegible]

Table—3

Effect of clarifying agents on colour intensity, ash and colloid contents of gur

Treatment no.	Colour value			Ash%			Total colloid %		
	1974-75	1975-76	1976-77	1974-75	1975-76	1976-77	1974-75	1975-76	1976-77
T ₁	88.2	144.5	107.2	4.83	4.0	4.3	8.4	8.4	9.7
T ₂	47.9	71.3	72.1	2.24	2.8	3.1	3.7	3.5	3.6
T ₃	51.1	73.4	71.1	2.99	3.0	3.2	4.3	4.0	3.7
T ₄	46.8	71.5	72.2	2.33	2.7	3.2	3.2	3.8	4.0
T ₅	79.8	94.8	92.1	3.87	3.6	3.9	4.4	6.5	7.0
S. E. (Tr) Mean	1.97	14.96	5.68	0.26	0.2	0.30	0.12	0.22	0.18
C. D. at 5%	6.07	46.09	17.50	0.80	0.62	0.91	3.70	0.68	0.54
C. D. at 1%	8.51	—	—	1.12	—	—	5.18	—	—

A COMPARATIVE STUDY ON THE CHEMICAL CHARACTERISTICS OF BO-70 VARIETY OF SUGARCANE OBTAINED FROM DIFFERENT REGIONS OF EAST UTTAR PRADESH AND BIHAR AND THEIR INFLUENCE ON THE COLOUR FORMATION AND CLARIFICATION DIFFICULTIES

By

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ABSTRACT

The BO-70 variety of sugarcane, mostly coming to Marhowrah Factory for crushing was systematically studied for some of the ash and colour contributing constituents, clarification and settling characteristics and the results were compared with those of the same variety of cane obtained at the same time from few other factories. As a result of series of analytical experiments carried out at Laboratory scale it was found that juice of Marhowrah cane was found to be peculiar in several respects. Few significant observations were the high ash having high content of SiO_2 , K_2O and P_2O_5 , high reducing sugars, low organic phosphate content, large quantities of colloidal matter and high polyphenolic content. This peculiar nature of the juice with respect to several constituents as mentioned above explained the difficulties experienced regarding clarification and sugar colour. Based on few laboratory experiments, some modifications to be adopted in factory working were suggested which were found to be helpful in reducing the formation of colorants and in improving the clarification.

Introduction

Marhowrah Sugar Factory of Cawnpore Sugar Works Limited, experienced a unique problem particularly regarding the sugar colour in the crushing season 1977-78. The quality of the sugar produced at Marhowrah

factory dropped sharply with considerable amount of fluctuations in sugar colour throughout the whole season. Frequently, reddish, blackish or greyish tinges were found to be associated with the sugar crystal, the extent of which increased with the advancement of crushing season. The Dorr juices were found

to be hazy, turbid and darker in colour. The processed juice could not settle well in Dorr the quality of final product affected seriously with the normal dose of milk of lime employed for clarification. Other factories of concern, viz. Barachakia, Chanpatia, Padrauna and Kathkuiyan ran smoothly and faced almost on such problems.

Keeping in view the above, the characteristics of the raw juice obtained from the variety of cane mostly coming to factory for crushing were systematically studied in great detail and results were compared with those of same variety of cane obtained from other factory areas viz. Barrah, Chanpatia (Bihar) and Padrauna, Kathkuiyan (East U. P.) which had no such problems. For conducting these experiments February planted BO-70 variety of sugarcane which is a major variety of the areas, harvested at the same time was selected. The clarification, settling and colour characteristics of the raw juices were also investigated at length. Studies were undertaken in order to understand the nature and extent of the various constituents responsible for clarification difficulties and imparting colour to sugar crystal.

Experimental

February planted sugarcane of BO-70 variety properly packed in gunny bags was obtained from Barachakia, Chanpatia, Marhowrah and Kathkuiyan, Padrauna regions of Bihar and east U. P. respectively. The cane was crushed on a power driven laboratory crusher ensuring that time lag between harvesting and extraction of juice in all cases was more or less same. During crushing distilled water was added to adjust the Brix of the

juice around 15.0. For each sample of cane the crushing was done three times in order to have identical conditions. The crusher juices obtained were systematically analysed for various parameters such as Bx, Pol, reducing sugars, CaO , K_2O , inorganic and organic phosphates, sesquioxides, sulphated ash, total amino acids and total polyphenolic content. Amino acids and total polyphenols were determined by spectrophotometric methods Wiggins and Williams¹, and Swain and Hill² respectively. All other parameters were determined by standard procedure generally adopted in sugar analysis. The clarification of the crusher juices was carried out by normal sulphitation process using 1.0, 1.5 and 2.0% milk of lime of 10° Be, and settling rate, turbidity, haziness and scum were observed by settling the clarified muddy juices in graduated 250 ml. measuring cylinders. The optical density values of clarified juices were measured at pH 7 on Beckman spectrophotometer model B at 420 nm. The indicative values of the raw juices were also determined as discussed later in this communication. These experiments were conducted in the first week of March.

Results and Discussions

Table I gives the results pertaining to Bx purity, sulphated ash% and few inorganic constituents of the raw juices of different cane samples. It may be seen from the table that the juice extracted from Marhowrah cane has the lowest purity as compared to others and indicated relatively poor sugar content in the cane of that area. The highest purity was recorded for the cane obtained from Chanpatia area. As evident from the results, the

Marhowrah juices were characterised in having highest value for sulphated ash (0.764%), the lowest being 0.527% which was recorded for Barachakia. Further, looking at the composition of the sulphated ash, it was interestingly observed that Marhowrah juice was especially marked in possessing high quantities of insolubles and silica, K_2O and sesquioxides. All these inorganic non-sugars are supposed to play vital role in the manufacture of sugar and are harmful when present in excessive amounts in the cane juice.³

Presence of considerably large quantities of silica present in the juice of Marhowrah were probably responsible for the clarification difficulties and also heavy scaling in the evaporators besides the turbid nature of the Door juice. The presence of higher quantities of Silica might impart greyish tinge in sugar crystals as the greyish tinge is known to be imparted by the siliceous acid which accumulates in the processed sugar⁴. Since the removal of silica is of quite special significance in relation to good clarification and needs high doses of calcium hydroxide and phosphate, the factory had to employ very high doses of milk of lime and additional P_2O_5 for improving the clarification. The formation of excessive foaming material as often observed during the processing of the raw juices in Marhowrah factory indicated the possibility of a part of the total potash content in the form of complex organic compounds⁵. The high content of potassium in these juices was perhaps one of the causes for the high percent of the molasses produced since the elimination⁶ of potassium during the clarification processes using sulphitation, is only very small. The greyish tinge in the sugar crystal as often

observed in Marhowrah factory during the crushing season 1977-78 may also be said to be attributed due to the presence of large amounts of potassium and sesquioxides in raw juices⁷.

It may be seen from the above that Marhowrah juices were characterised in having high content of ash which itself was found to be rich in silica, potassium and sesquioxides. These ash contributing constituents present in excess in raw juice created difficulties in clarification and processing and created problems in the boiling house besides in making good quality of white sugar.

Constituents responsible for colour formation :

(1) Reducing sugar content :

The cane juices of Marhowrah were significantly marked in their high reducing sugar content (Table 2). The value when calculated on 100°Bx was found to be 7.98 while the lowest value of 1.45 was recorded for Barachakia. It may be stated that the high values of reducing sugar content are liable to cause difficulties during heating and liming of the juice as there is always possibility of conversion of part of it into organic acids which may react with lime to produce calcium salt of these acids which causes serious problems in further processing mainly regarding the scale formation in evaporators. Moreover the reducing sugar may form colouring compounds as a result of their alkaline degradation⁸ if temperature and pH conditions are not properly maintained.

(2) Total Amino Acid content :

The results showed that the juices of Marhowrah cane were characterised in having neither very low nor very high amino acid content (Table 2). The maximum value of 729 mg/l evaluated on 100° Bx was found for juices of Barachakia cane while the lowest of 499 mg/l was observed for Kathkuiyan. All these values were supposed to be too low to cause colour formation difficulties via melanoidins formation. The juices of Palia and Gola factories who experienced the difficulties of excessive melanoidins formation during the concentration of clarified juices and syrups, had amino acid content⁹ as high as 1600-2600 mg/l on 100° Bx. As compared to the high level of Amino acids found in other factories as reported earlier,⁹ the Amino acid content in Marhowrah juices was much lower and thus much less chances are of colour formation melanoidins type.

(3) Total polyphenolic compounds :

The Marhowrah juice was especially characterised in having high polyphenolic content in comparison to the juices of other places (Table 2). The high concentration of total polyphenols creates difficulty regarding the colour formation which impart additional colour to sugar crystal. The colour formation by such compounds occurs in two ways.¹⁰ Firstly, through enzymatic browning of polyphenols which takes place by the oxidative reactions the these polyphenols catalysed by the certain enzymes. Such browning may be inhibited by heating cane stalks prior to cutting and crushing. Theoretically how far such a step is possible on such a large scale

and magnitude is a matter which may not be accepted practically. Secondly, the formation of coloured complexes of polyphenols with iron is an established possibility where juices syrup remain in contact with Iron right from the stage of extraction to sugar. It may therefore, be mentioned that the large quantities of polyphenolic compounds present in Marhowrah juice are also responsible for the comparatively poor quality of sugar (in colour) in relation to other factories.

(4) Colour development in juice (anthocyanin)/HCl reaction :

The polymetric compounds Anthocyanins which are in nature are soluble in water and are organic compounds of glucoside group. They give a characteristic red colour reaction¹¹ with strong hydrochloric acid. This property of anthocyanin compounds was made use of, in making a rough comparative study of the extent of anthocyanin in different juices. For this a known quantity of filtered raw juice was mixed with 5% HCl, and was heated for some time and after cooling, it was filtered. The optical density of the filtered red juice after 1 : 10 dilution was measured at 420 nm. The studies showed the highest value (0.44) for Marhowrah juice thereby indicating the high concentration of anthocyanins in it (Table 2). This was further supported by the high content of total polyphenols observed for Marhowrah juice since total polyphenols, as determined by the methods of Swain and Hills, include anthocyanins also. It may also be mentioned here that colour formation difficulties might also be considered because of the formation of dark coloured complex of iron with anthocyanins, both being found in abundance in Marhowrah juices.

(5) pH-Sensitivity of colouring matter of different juices :

The pH sensitiveness of the colorants associated with the raw juices of different canes was evaluated by the method of Smith¹² by measuring the optical densities of filtered juice at pH 4 and 9. (Table 2). The indicator value was obtained by taking the ratio of O.D. at pH 9 and O.D. at pH 4, both measured at 420 nm. The results indicated the highest indicator value of 5.00 for Marhowrah juices and pointed out the high content of naturally occurring plant pigments having low molecular weights particularly flavanoids which are characterised in having conjugated polyphenolic structure. These findings further confirmed the higher presence of total polyphenols in the juice of Marhowrah cane.

(6) Colloids (Gums) :

The alcohol precipitable matter was determined in all the juices. The results showed the highest content (0.0924%) observed for Marhowrah cane, the lowest being recorded for Kathkuiyan (Table 2). It is well known that large quantities of colloidal matter present in cane juices generally impose problems viz: increase in viscosity of the syrups and molasses, foaming, increase in colour, retardation in the boiling, hampering the efficient working in the centrifugals and in general reduction of capacity of the factory. Increase in viscosity in massecuites and molasses were observed in a greater magnitude at Marhowrah. On the other hand at Kathkuiyan Factory where the colloidal content was found to be lowest ran smoothly and was able to produce good

quality white sugar with no clarification difficulties.

(7) Phosphate Content of the Juices :

The phosphate content of the juices of cane obtained from different places were determined both for inorganic (available) and organic form, which gave quite interesting results (Table-3). Such studies were also conducted for clarified juices of the respective raws. For raw juices the total P_2O_5 content varied from 373.60 to 452.80 mg/l out of which 312.15 to 396.75 mg/l was estimated in the form of inorganic phosphate whereas 38.25 to 87.15 mg/l was in the form of organic phosphate. Similarly, for clarified juices, total P_2O_5 content varied from 40.35 to 55.60 mg/l, inorganic being from 15.95 to 25.10 while organic, from 23.15 to 35.75 mg/l. It may be observed from the results that although inorganic phosphate content of the Marhowrah juice was not very low as compared to others, the organic phosphate was found to be lowest, i.e. 38.25 mg/l. Further it was of interest to note that even organic phosphate of the raw juice might have taken part in the reaction system during sulphitation of the juices which was found to be quite obvious from the results of organic phosphate content of the corresponding clarified juices which were always found to be lower from the organic phosphate of their respective raw juice. This involvement of organic phosphate might possibly be due to the breaking in part of few carbon phosphorous linkages during the clarification reaction thereby converting a part of the organic phosphates into the inorganic one. This phenomenon seems to be

quite interesting and needs further going into. Under similar condition of clarification, the total quantity of phosphate actually utilised for clarification was found to be lowest (328.80 mg/l) for the juice sample of Marhowrah cane and which may possibly one of the important factors for poor clarification.

(8) Settling characteristics of juices :

Fig. 1 indicates the settling characteristics of the different juices obtained as a result of clarification employing 1.5% milk of lime of 10° Be in each case. The best settling was observed in case of Kathkuiyan cane juice which showed a steep fall of mud with larger flock formation and absence of any turbidity, haziness or scum volumes. On the other hand, the Marhowrah juices were found to have comparatively low settling rates, little haziness and turbidity in clear juice and small amounts of scums. The lowest mud volume was observed in case of Padrauna juice while the highest one in case of Marhowrah. Low settling rate, haziness, turbidity and small volumes of scum observed in Marhowrah juices may be due to the low phosphate content actually utilised during the clarification, high polyphenols, high colloidal content and large amounts of silica present in raw juice. The behaviour of tannins (polyphenols) in disturbing the settling and clarification has already been pointed out 13.

(9) Optical Density values, colour tinges and turbidity of clarified juices :

Table 5 indicates the optical density values measured at 420 nm at pH 7 (dilution 1:3), colour tinge and turbidity, if any, of the clarified juices obtained by clarifying raw juices of

different cane samples, using different lime doses. It was observed from the studies that the lime dose used for clarification had a direct impact on the optical density of the clarified, juices. Thus, as the lime dose was increased, there appeared a fall in optical density values. For a fixed lime dose, the O. D. value varied for different juices. Thus at 1.5% lime dose, the variation occurred was 0.095 to 0.13. The lowest value of 0.095 was observed for Chanpatia sample whereas the highest one 0.13 for Padrauna. It was quite interesting to observe that the O. D. of the clarified juice was reduced although to very small amount, in going from 1.5% to 2.0% lime dose for all the samples except for Marhowrah which had the same O. D. value at the two lime doses. This showed that even the increased lime dose (from 1.5 to 2.0%) was unable to reduce the extent of colour of clear juice in case of Marhowrah. For Chanpatia, Marhowrah and Padrauna the juices were found to be slight turbid at 1.0% lime dose. This turbidity disappeared by increasing the lime dose to 1.5% in case of Chanpatia and Padrauna. But it was of interest to observe that for Marhowrah juice, turbidity/haziness persisted even by employing lime doses upto 2.0% although their intensities were reduced to some extent. The presence of slight haziness and turbidity observed even by using high doses of milk of lime as observed in case of Marhowrah juices may be an individual and or resultant effect of low phosphate, high reducing sugar, high polyphenolic compounds and high SiO₂ content.

Another striking feature noted for Marhowrah juices was the presence of greenish tinge in clarified juices the intensity of which

decreased as the lime dose was increased. The clarified juices of other places produced golden yellow colour with very slight yellowish or reddish tinge. Since anthocyanin compounds are turned green by their reaction with milk of lime used for clarification, the greenish tinge observed in clarified juice of Marhowrah was considered to be due to this category of compounds present in considerably high quantities as has already been pointed out. The reduction of the intensity of the greenish tinge on increasing the lime dose further pointed out that the anthocyanin compounds could be subsequently removed by increasing lime dose. This, however, is subjected to further confirmation. It could thus be seen from the above discussions that the juice of Marhowrah cane behaved in a peculiar manner. It was characterised in having low purity, high ash % high reducing sugar content, high polyphenolic compounds, low organic phosphates and high colloidal content. Ash itself was found to be rich in K_2O , silica and sesquioxides. Apart from these, the juices showed slow settlings with turbidity and haziness in the clarified juices. The colouring matter associated with Marhowrah raw juice was found to be comparatively high pH-sensitive type.

In order to find a solution to the typical Marhowrah juices, studies in respect of clarifying the same in Laboratory employing various permutations were undertaken. Thus, in a set of experiments carrying out clarification at different doses of milk of lime, it was observed that the best suited lime dose was in the

range of 2.5—3.0%. By using these lime doses, the juices behaved nicely. The O. D. value of the clarified juice was found to be considerably low and turbidity and haziness almost nil. In such clarified juices the greenish tinge was also absent. In another set of experiments, clarification of the mixed juices was performed after the addition of extra P_2O_5 content added to raw juices in varying amounts. The studies revealed good settling and clarification when the quantity of additional P_2O_5 dose was 75 mg/l (The original P_2O_5 in mixed juices was of the order of 280–320 mg/l). In a separate experiment, both the operations, i.e. addition of extra 75 mg. P_2O_5 per litre and preliming were adopted. Fig. 2 indicates the settling curves of clarified muddy juices obtained by following few such operations. It was observed that the best clarification and settling could be achieved when both operations, viz. additional P_2O_5 and preliming were adopted. The O.D. of clear juices was also found to be considerably low having no turbidity or greenish tinge. It may be stated that when these modified operations, viz. addition of extra P_2O_5 and preliming were adopted, the factory had improved the clarification and quality of final product.

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Table-1
Analysis of Raw Juices for Sulphated Ash and Some of Its Constituents

Factory	Corr Bx.	Pol. %	Purity	Sulphated Ash%	(CaO+MgO) ----- mg/l	Fe ₂ O ₃ +Al ₂ O ₃ ----- mg/l	Insolubles and SiO ₂ ----- mg/l	K ₂ O ----- mg/l
Barachakia	15.36	13.59	88.47	0.527	880	182.85	312.9	885
Chanpatia	15.17	13.82	91.10	0.685	760	130.48	512.8	830
Kathkuiyan	16.81	14.44	85.90	0.648	1280	74.62	158.2	926
Marhowrah	15.29	12.83	83.91	0.7640	840	168.62	832.5	1156
Padrauna	15.74	13.60	86.40	0.6640	1170	95.13	428.1	952

Table--2
Analysis of Juices for Some Constituents Responsible for Colour Formation

Factory	Corr. Bx.	Reducing Sugar % 100 Bx.	Amino Acid mg/l on 100 Bx.	Total polypheno- l mg/l on 100 Bx.	Optical density measured at 420 nm at pH.			Indicator value	Colloids (Gum %)	Colour deve- loped in juice (anthocyanin) HCl. Reaction
					4.0	7.0	9.0			
Barachakia	15.36	1.45	729	3997	0.11	0.25	0.43	3.91	0.0466	0.39
Chanpatia	15.17	1.58	527	2703	0.08	0.12	0.27	3.37	0.0506	0.21
Kathkuiyan	16.81	5.76	499	4174	0.14	0.20	0.38	2.71	0.0394	0.27
Marhowrah	15.29	7.98	588	5019	0.09	0.28	0.45	5.00	0.0924	0.44
Padraura	15.74	1.91	581	4130	0.16	0.25	0.45	2.8	0.0688	0.35

Table—3
Phosphate content (P_2O_5) of raw juices and their clarified juices (1.5% lime dose) in mg/l

Sl. No.	Factory	Raw Juice		Clarified Juice		Total quantity of Phosphate used for clarification
		Inorganic	Organic	Inorganic	Organic	
1	Barachakia	362.15	58.35	20.25	35.35	364.90
2	Chanpatia	396.75	56.05	25.10	30.45	397.25
3	Kathkuiyan	312.15	87.15	15.95	35.75	347.60
4	Marhowrah	335.35	38.25	21.65	23.15	328.80
5	Padrauna	339.65	75.15	15.25	25.10	374.45

Table-4
Final mud volumes in ml. of juices, clarified with different lime doses

Factory	1.0%	1.5%	2.0%	Scum, if any
Barachakia	66	52	44	Nil
Chanpatia	70	58	50	Nil
Kathkuiyan	62	48	40	Nil
Padrauna	64	46	44	Observed (small amount)
Marhowrah	88	68	55	Observed (very small)

Table - 5
Optical Density Values and Colour Tinges of Clarified Juices.
(Dilution 1 : 3) At pH = 7.00 Measured at 420 nm.

Factory	1.00% lime		1.5% lime		2.0% lime	
	O. D.	Colour Tinge & Turbidity	O. D.	Colour Tinge and Turbidity	O. D.	Colour Tinge and Turbidity
Barachakia	0.12	Golden yellow, Clear solution	0.11	Golden yellow, Clear solution	0.105	Golden yellow, Clear solution
Chanpatia	0.11	Yellow with reddish tinge, Slight turbid	0.095	Yellow with light reddish. Clear solution	0.10	Golden yellow, Clear solution
Kathkuiyan	0.135	Golden yellow with slight reddish tinge	0.120	Golden yellow Clear solution	0.125	Light yellow Clear solution
Marhowrah	0.105	Yellow with greenish tinge, Very turbid	0.100	Yellow with greenish tinge, turbid	0.100	Golden yellow with light greenish tinge, Slight turbid
Padrauna	0.15	Yellowish red, Slight turbid	0.13	Golden yellow Clear solution	0.135	Golden yellow Clear solution

SETTLING CHARACTERISTICS OF JUICES OF
CANE OBTAINED FROM DIFFERENT PLACES
(25% LIME OF 10° Be USED FOR SULPHITATION IN EACH CASE)

B BARRAH CHAKIA
C CHANPATIA
K KATHKULJAN
M MARHOURAH
P PAORAUNA

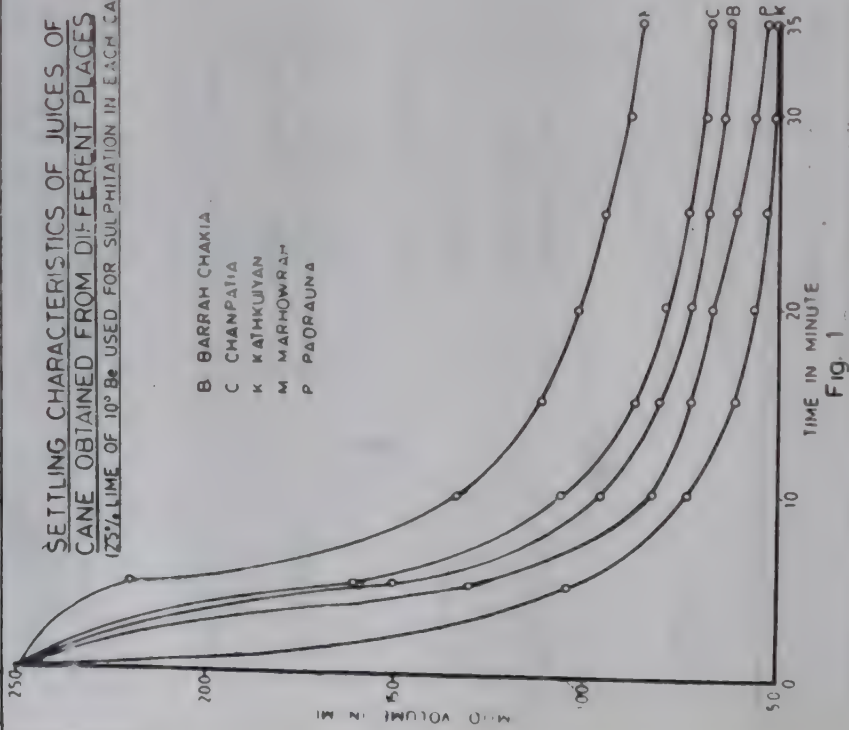


Fig. 1

EFFECT OF ADDITIONAL P₂O₅ DOSE PRELIMING
& BOTH ON THE SETTLING CHARACTERISTICS OF
THE JUICES

1 MIXED JUICE IM JI
2 M J WITH 75mg/l P₂O₅
3 M J WITH PRELIMING
4 M J WITH 75mg/l P₂O₅ & PRELIMING

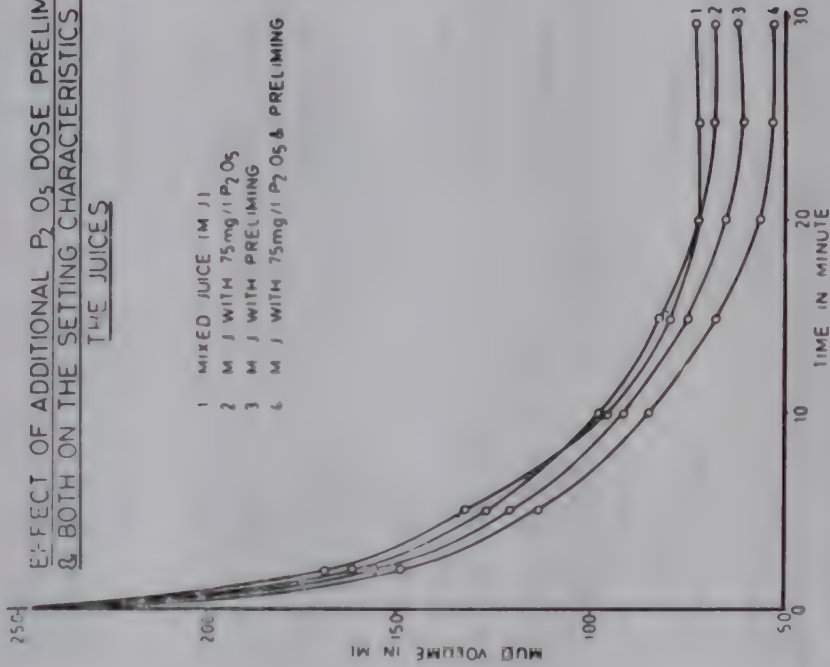


Fig. 2

NETWORK ANALYSIS—AN AID IN PLANNING SUGAR INDUSTRY PROJECTS

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ABSTRACT

The paper stresses the importance of adopting modern project planning techniques particularly in execution of new sugar factory projects or for expansion of existing factories. The usefulness of CPM and PERT network analysis for this purpose has been highlighted.

Network planning is a powerful tool in the hands of project management staff. It not only allows a more effective control on the progress of the project but also enables planning of all material and manpower resources allocation in controlled and scientific manner. This is a vital necessity to control the project cost over-runs and for implementation of an essentially time bound project on schedule.

Introduction

Project planning is important for any industrial project, but it is more crucial for sugar industry that depends on a costly and perishable raw material like sugar cane. The erection and commissioning of a new sugar factory or expansion of an existing factory has to be completed on its scheduled time i. e. before the start of a crushing season, otherwise, not only heavy financial strains will be

imposed on the factory but the cane farmers will also suffer serious losses.

Unlike, any other industry, the equipment used in a sugar factory are heterogeneous one, varying from a simple storage tank to highly sophisticated equipment like control instruments, steam turbines, boilers for steam generation, juice extraction mills, diffuser etc. This indicates that sugar projects have a wide and varied range of suppliers with different

delivery time schedules for equipment, varying from a few days to many months. Also, some of the equipment are very expensive and require large financial commitments from the initial stage of the project work. Therefore, it becomes imperative on the part of the management to plan the limited financial resources in a way so as to avoid over-commitments at any one particular occasion and to incur minimum interest over the borrowed capital.

The existing practice in procuring an item is to place an order on the supplier at the convenience of the management and then expedite or postpone the delivery to suit overall progress of the project. This not only results in blockage of capital & rise in cost but also creates an atmosphere of uncertainty between the supplier and buyer.

An Approach to Modern Project Planning

Until recently the execution of a project was done with little or no planning. The best known tool then was the so-called (Gantt) bar charts which specifies the start and finish times for each activity on a horizontal time scale. The disadvantage here is that interdependency between the different activities, which mainly control the progress of a project, cannot be determined. This has demanded systematic and more effective planning techniques with the objective of optimizing the efficiency of executing a project. Efficiency in this case would call for completion of a project on a date which is neither earlier nor later than the one predetermined by various factors comprising of availability of material, finances, man-power, etc. While it may be possible

to complete a project at an earlier date, the various factors involved may not permit it to be commissioned, in which case also the idle time will result in financial losses due to the dis-use of committed capital.

With the growing complexities of projects, all project Executives are faced with the identification of following critical points :

To define the objectives

To plan the actions

To organize the work

To make the participants communicate with each other

To control the results.

Various approaches were developed in the past to plan a project with considerations of all above points. Among them network analysis has been found to be most up-to-date and comprehensive project planning technique.

What is Network Analysis

Project Management has evolved as a new field with the development of two analytical techniques for planning, scheduling and controlling of projects. They are Critical Path method (CPM) and Project Evaluation and Review Technique (PERT). The two techniques were developed by two different groups, almost simultaneously (1956-58). CPM was first developed by E. I. du-Pont de-Nemours Company as an application to construction projects and was later extended to a more

advanced status by Mauchly Associates. PERT, on the other hand, was developed by the U.S. Navy for scheduling of Navy Research and Development activities for Polaris Missile programme, which involved 250 suppliers and 9000 sub-contractors.

PERT and CPM are basically time oriented methods in the sense that they both lead to the determination of a time schedule for a project. Although the two methods were developed almost independently, they are strikingly similar. Perhaps the most important difference is that, in CPM the time estimates for different activities were assumed to be deterministic, while in PERT these time estimates are normally based on the Beta distribution with optimistic, pessimistic and most likely time estimates as parameters. Today PERT and CPM actually comprise one technique and the differences, if any, are only historical.

Project Analysis Through Network

A project consists of three basic phases—planning, scheduling and controlling.

The planning phase is initiated by breaking down the project into distinct activities and then developing a logical sequence among them. The broad outline for any project planning are :

- (a) Determination of project objectives (Hierarchical Breakdown)
- (b) Analysis of the activities (definition, duration and constraints).

- c/ Development of a network and study of the logic.

The Arrow diagram (Network) graphic representation of the interdependencies the activities of a project. The construction of the Network as a planning phase yield the advantage of studying the different jobs in detail, perhaps suggesting improvement before the project is actually executed.

The aim of the scheduling phase is to construct a time chart showing the start and finish time for each activity as well as its relationship to other activities of the project. The schedule must pin-point the critical activities which require special attention, if the project is to be completed on time. The scheduling phase will comprise of.

- (a) Calculation of the Network and study of the critical path.
- (b) Drawing up of executive documents (time scale planning).
- (c) Establishment of costing diagrams.

The final phase in project management is controlling. This includes the use of network and the time-charts for making periodic progress reports. The network may thus be updated and analyzed and, if necessary, new course of actions are determined for the remaining portion of the project.

Aid For Sugar Projects

To demonstrate the usefulness of Network Analysis for sugar projects, we are discussing hereunder some details of one of our expansion

project for which our company was retained as consultants. The main objective of the project was to increase the crushing capacity of the plant from present 2300 TCD to 3600 TCD in two years' period, using existing equipment as much as possible. The illustration of the complete project will be very difficult for presentation in this paper, and therefore, a part of the project has been selected for this purpose. In fact, for any project analysis, it is essential to divide the project into many sub-projects and then study their interactions.

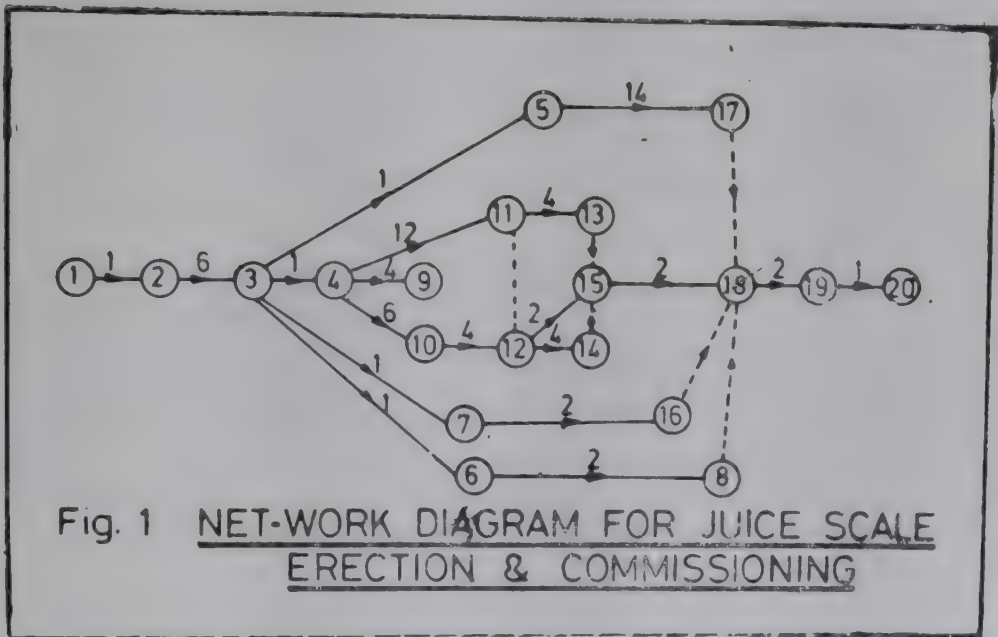
The Problem

The problem we have discussed hereunder is of erecting and commissioning of a new Automatic Juice Weighing Scale at the expanded capacity. Because of lay-out constraints, it was decided to erect the new scale at different location. This also ensures

that the functioning of the existing plant was not disturbed. To analyse the system, the project is segregated into various activities in a logical sequence to indicate the course of action to be adopted (Table-1). An activity in this case is defined as an individual job, requiring time and resources for its completion and it is specified by two nodes to indicate the starting and completion points. For example, the finalisation of purchase order specifications take 1 week time and is shown by activity number (1, 2). On basis of these activities, a Network was developed to indicate their interactions. For example, the layouts and foundation details cannot be finalized until and unless the purchase specifications are finalized and orders have been placed (Fig. 1). The ordering of various equipment e. g. pumps, motor, piping etc., can be done simultaneously but the date of ordering will vary according to their delivery periods.

To determine the scheduling of various activities, calculations are done on the network to determine the earliest start and completion time, latest start and completion time and total float time for each one of them. The total float time for an activity is defined as

the slack time available to perform an activity i. e. period during which, if the activity cannot be performed, no serious affect will be experienced on completion of the project. The calculations for these time periods are done on the basis of following formulae



$$1/ \text{ES}_j = \text{Max}_{i,1} (\text{ES}_i + D_{ij}) \text{ for all defined } (i, j) \text{ activities}$$

$$2/ \text{LC}_i = \text{Min}_{j,1} (\text{LC}_j - D_{ij}) \text{ for all defined } (i, j) \text{ activities}$$

$$3/ \text{TF}_{ij} = \text{LS}_{i,1} - \text{ES}_i \text{ for all defined } (i, j) \text{ activities}$$

Where— ES_j — Earliest start time for all the activities emanating from event j .

ES_i — Earliest start time for all the activities emanating from event i .

D_{ij} — Duration of an activity i, j .

LC_i — Latest completion time for all activities coming into event i .

LC_j — Latest completion time for all activities coming into event j .

$\text{LS}_{i,j}$ — Latest start time for an activity i, j .

$\text{TF}_{i,j}$ — Total float time from an activity i, j .

The calculations of earliest start and completion time are done by forward pass method wherein the calculation begins from the "Start" node and move toward the "End" node. At each node a number is computed to represent the earliest occurrence time of the corresponding activity. This has been represented by square, $\square$ on the final network shown in Fig. 2. Similarly the calculations for latest start and completion time are done by backward pass method wherein the calculation begins from the "End" node and move toward the "Start" node. The calculated number for each node are represented by triangles, Δ in the network in Fig. 2. For example for an activity (4, 10).

$$\text{ES}_{10} = \text{Max.}_{4 \text{ to } 9} (\text{ES}_4 + D_{4,10}), (\text{ES}_9 + D_{9,10})$$

$$= \text{Max.}_{4 \text{ to } 9} (8 + 6), (12 + 0)$$

$$= \text{Max.}_{4 \text{ to } 9} (14, 12) = 14$$

$$\begin{aligned}
 LC_4 &= \min_{9, 10, 11} (LC_{10} - D_{4,10}), (LC_9 - D_{4,9}), (LC_4 - D_{4,11}) \\
 &= \min_{9, 10, 11} (16-4), (16-6), (20-12) \\
 &= \min (12, 10, 8) \\
 &= 8
 \end{aligned}$$

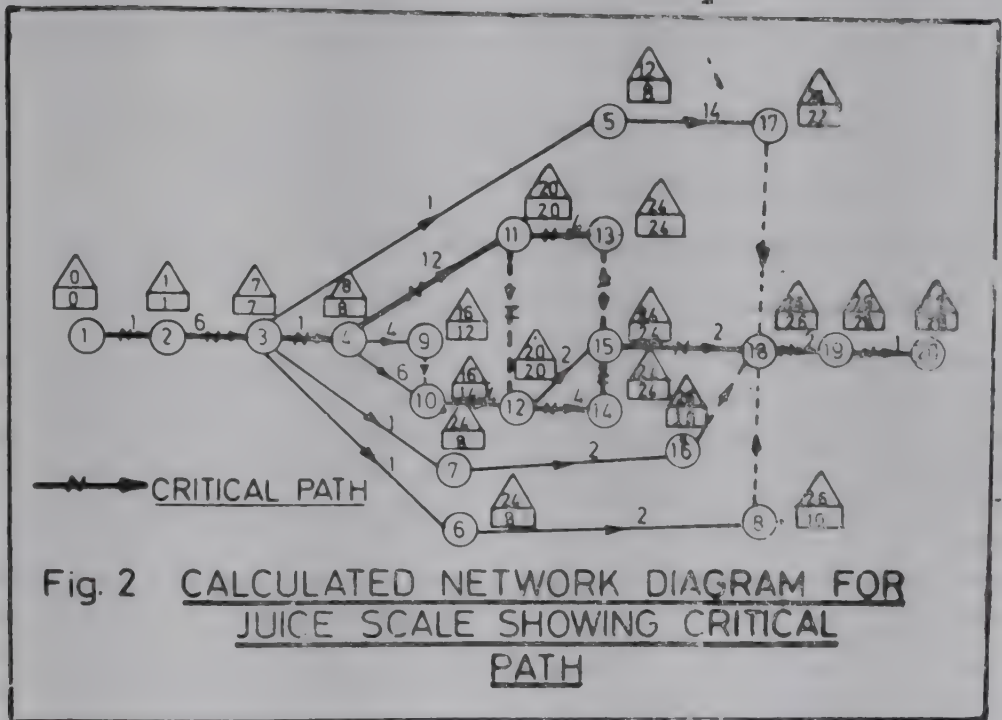


Fig. 2 CALCULATED NETWORK DIAGRAM FOR JUICE SCALE SHOWING CRITICAL PATH

The details of calculation for earliest start and completion time, latest start and completion time and total float time for each activities are shown in Table-2.

This suggests that the activities falling on the critical path have a zero slack time and they must be executed on their scheduled time. Otherwise, the project may not be completed on time unless the duration of the following activities are reduced which may eventually give rise to the increase in project cost.

Also on basis of the calculations shown in Table-2, time charts are developed according

to the calendar time to indicate the start and completion date of various activities (Fig.- 3). The calendar time charts were prepared by pre-fixing the final commissioning date of the juice scale and then making back calculations to determine the starting and completion dates of other activities. The final commissioning date of the juice scale in this case was assumed to be September 30, as the crushing season starts in October end.

Results and Discussions

From the calculations shown in Table —2, the following activities on network path 1-2-3-4-11-13-15-18-19 are found to be critical —

1. Finalisation of purchase order specifications—March 11 to 18.
2. Completion of enquiries with different manufacturers—March 18 to April 29.
3. Placing purchase order on the manufacturer for main equipment—April 29 to May 6.
4. Procurement of main juice scale equipment—July 29 to August 26.
5. Erection of main equipments—August 26 to September 9.
6. Erection of pump and piping—September 9 to 23.
7. Electrical connection—September 23 to 30.

The above activities must be started and completed on their due date in order to complete the project on time. If any of the above activities are not adhered to their time schedule, then either the project may not be completed on its due date or if it is any how completed then the cost would be higher than budgetted.

The non-critical activities shown in Fig. 2 indicate that they may be started some time in between their earliest and latest starting date. The time available to start is shown by total float value for each activities. Also these activities must be completed before their latest completion date, otherwise some different critical path will appear and a different course of action has to be adopted to complete the project. This may again give rise to increase in project cost.

The total time required for commissioning of the new juice scale is determined to be approximately 7 months starting from very initial stage of purchase specifications to the

final trial stage. The date of ordering and procurement of various equipment are determined so as to complete the project on time. On basis of these dates, the capital requirements can be determined and arrangements can be made with the financial institutions. If at any stage of project implementation, difficulties arise in executing a particular activity, then the project can be easily reviewed and an alternate course of action can be adopted to complete the project on time.

The results of this technique can be best achieved, if both supplier and buyer adhere to their scheduled programme.

Summary & Conclusions

The network analysis is the most recent and upto date technique for planning scheduling and controlling of any project. The usefulness of the technique has been demonstrated for a sugar factory project by selecting a specific example of erection and commissioning of a

new juice scale. The details of equipment ordering foundations and erection are determined so as to make financial and manpower arrangements. Likewise these details for other equipment of sugar factory can be determined and final scheduling for the complete project can be determined. This does not only give better control on the progress of the project but will also maintain the cost as visualized earlier at the time of project inception.

Acknowledgements

The author is deeply indebted to Mr. G. Sawhney, Chief Executive for his keen interest and able guidance during the course of this work.

Sincere thanks are due to Mr. V. C. Srivastava for his encouragement and creative suggestions to improve the quality of this work.

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Table-1

Description of Activities for Erecting & Commissioning of Automatic Juice Weighing Scale

Sl. No	Description of Activities in a Logical Sequence	Duration of Activity in Weeks	Activity Number on Net Work Shown in Fig. 1
1	Finalize purchase order specifications	1	(1, 2)
2	Float enquiries	6	(2, 3)
3	Finalize purchase orders for main equipment	1	(3, 4)
4	Finalize purchase orders for pumps	1	(3, 5)
5	Finalize purchase orders for motors	1	(3, 6)
6	Finalize purchase orders for juice piping	1	(3, 7)
7	Receive G. A. drawing & finalize layouts	4	(4, 9)
8	Receive foundation details & finalise details of foundation	6	(4, 10)
9	Procurement of Construction material for foundations partly completed	4	(10, 12)
10	Procurement of main equipment partly completed	12	(4, 11)
11	Erection partly completed	2	(12, 15)

Contd.

Sl No	Description of Activities in a Logical Sequence	Duration of Activity in Weeky	Activity Number on Net Work Shown in Fig. 1
12	Foundation are completed	4	(12, 14)
13	Procurement of main equipment completed	4	(11, 13)
14	Erection of main equipments completed	2	(15, 18)
15	Procurement of pumps completed	14	(5, 17)
16	Procurement of electric motors completed	2	(6, 8)
17	Procurement of piping completed	2	(7, 16)
18	Erection of pump and piping completed	2	(18, 19)
19	Electrical connection completed	1	(19, 20)

Table—2

Details of Calculation For Earliest and Latest Time Schedule

Activity No. (i, j)	Duration In Weeks D. i. j.	Earliest		Latest		Total Float Tfij
		Start ESi	Comple- tion Ecij	Start Lsij	Comple- tion Lcij	
(1, 2)	1	0	1	0	1	0
(2, 3)	6	1	7	1	7	0
(3, 4)	1	7	8	7	8	0
(3, 5)	1	7	8	11	12	4
(3, 6)	1	7	8	23	24	16
(3, 7)	1	7	8	23	24	16
(4, 9)	4	8	12	12	16	4
(4, 10)	6	8	14	10	16	2
(4, 11)	11	8	20	8	20	0
(5, 17)	14	8	22	12	26	4
(6, 8)	2	8	10	24	26	16
(7, 16)	2	8	10	24	26	16
(8, 18)	0	10	10	26	26	16
(9, 10)	0	12	12	16	16	4

(Contd.)

Activity No. (i, j)	Duration In Weeks D. i. j.	Earliest		Latest		Total Float T _{fij}
		Start E _s i	Comple- tion E _c ij	Start L _s ij	Comple- tion L _c ij	
(10, 12)	4	14	18	16	20	2
(11, 12)	0	20	20	20	20	0
(11, 13)	4	20	24	20	24	0
(12, 14)	4	20	24	20	24	0
(12, 15)	2	20	22	22	24	2
(13, 15)	0	24	24	24	24	0
(14, 15)	0	24	24	24	24	0
(15, 18)	2	24	26	24	26	0
(16, 18)	0	10	10	26	26	16
(17, 18)	0	22	22	26	26	4
(18, 19)	2	26	28	26	28	0
(19, 20)	1	28	29	28	29	0

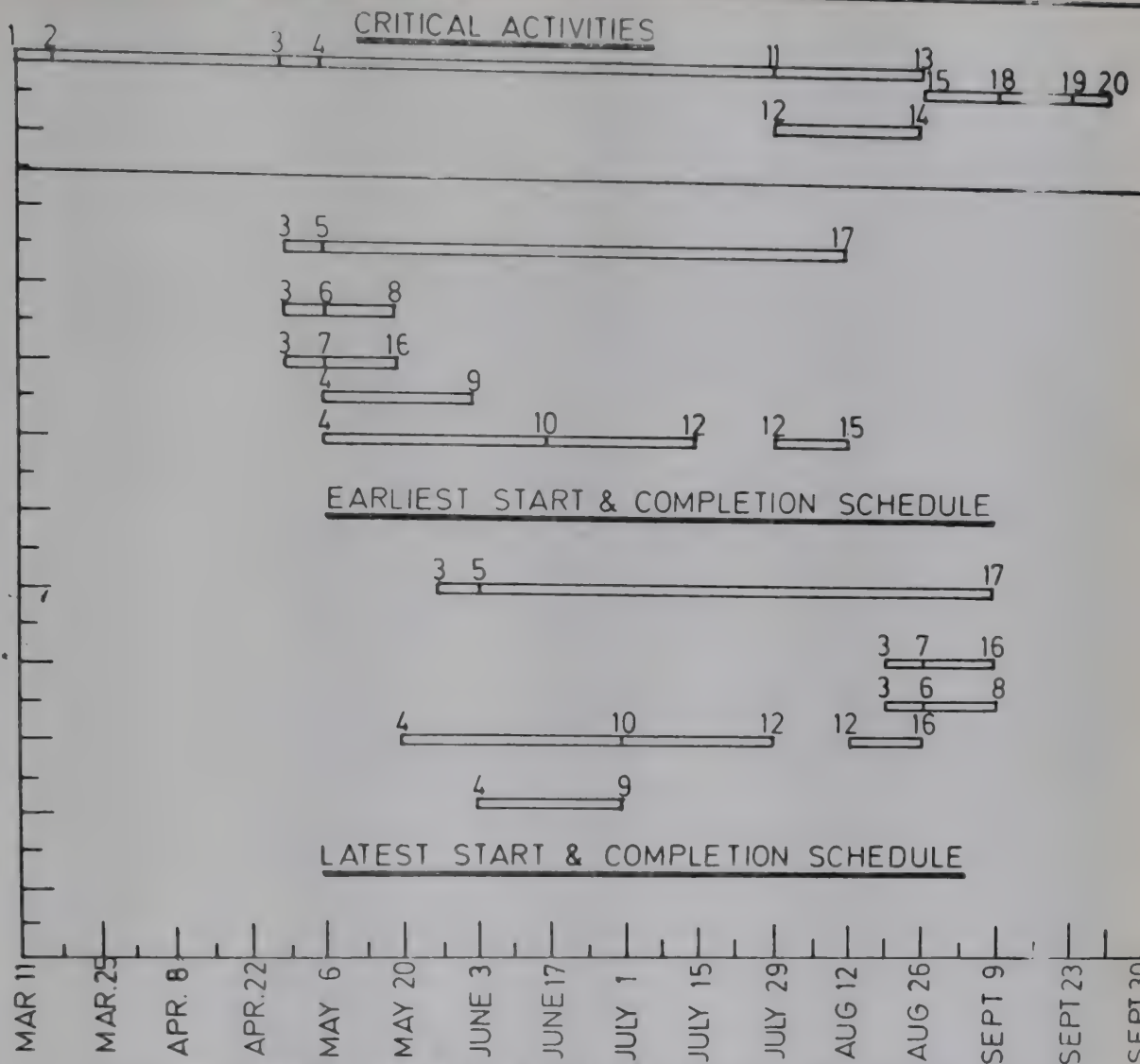


Fig. 3 TIME CHART FOR CRITICAL & NONCRITICAL ACTIVITIES

STUDIES ON THE USE OF FLOCCULATING AGENTS DURING SUGAR CANE JUICE CLARIFICATION BY SULPHITATION PROCESS

By

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ABSTRACT

The flocculating efficiency of an indigenous flocculant namely califloc A was tested with limed and sulphited sugar cane juice in the laboratory. A comparison with Seperan AP 30 revealed that the performance of the califloc A was very near to that of Seperan AP 30.

Introduction

The quality of cane juice obtained in a sugar factory, often varies with the cane quality, maturity, time of harvesting and other agromonomical practices. It has been observed that some times under same working pattern, the mud level in the clarifier often vary widely though this aspect is not thoroughly studied or taken care of in routine working. It often changes the ratio of settled juice and unsettled muddy portion quite significantly so much so that some times the mud level can be maintained very low and at other times inspite of all precautions, it goes out of control.

When there is poor settling, the only course left for the factory is to decrease its

crushing rate, other alternative may be to invest large sums for the purchase of additional subsidier and filtration equipments.

Coagulation of small particles to form large and lasily settled floc is hindered in case of refractory and draught condition juice. In order to improve the flocculation leading to rapid settling and thicker muds, many poly-electrolytes, naturally occuring poly-electrolytes and synthetic organic resinous polymers of anionic, cationic or non-ionic in character have been employed from time to time. The particles not aggregated generally yield to the poly-electrolytes. Moreover aggregation of the flocs already formed also takes place.

Hale and Whayman have given the theory of flocculants and the probable mode of action of flocculants. The formation of a bridged three dimensional net work produces faster settling rates and clearer supernatants as the floc are much larger and include the very small particles, which otherwise will not settle. In filtration the floc structure improves the porosity because of the fact that considerable void space is available within the flocs and improves the retention of small particles within the space.

Synthetic high polymers are poly anions and are either poly-acrylates, poly acrylamides, partially hydrolysed poly acrylonitriles or copolymers of vinyl acetate and maleic anhydride. They exist in the form of thread like long chains and the molecular weight in the region of 3000 is necessary, for the molecule should be long enough to bridge the gap between two adjacent molecules of suspended matter. These synthetic poly electrolytes are effective in very minute doses.

Separan AP₃₀²⁻³, Sedipur TF₂¹⁻² have been used which have been giving good results. These are imported products and the need for their substitution by indigenously manufactured flocculants was therefore imperative.

Number of indigenously manufactured flocculants 11-13 such as Flocal LT-26/25, Flocal LT 26/50, Flocal TN 40, Tulsepar A-30 and A-40, Floxin A-10, Boze floc A-51 B. T., Boze floc A-61 B. T., Prima floc A-10 and Hyflock, Morar floc A-40 M, Bedenol OT have been tried by various workers.

The samples of califloc A was made available to us by the Calico Chemicals and Fibres

Division, Bombay. Califloc A is an anionic polymeric solution in water having 50% solid content. It is miscible with water and forms a solution without any floc, while preparing solution, violent stirring should be avoided, at the same time it should be mixed thoroughly.

The present investigation was, therefore, undertaken to study the effect of the califloc A on the settling of limed and sulphited juice in laboratory and also to compare their flocculating abilities with that of Separan A A-30.

Experimental

The optimum dose of milk of lime was first determined which was found to be 1.8% by volume of 12° Be.

A .1% solution of the califloc was prepared. Raw juice was heated to 65°C and then limed and sulphited using 1.8% milk of lime of 12° Be.

500 ml each of the limed and sulphited juice was taken at six places. These were heated to boiling separated in six flat bottomed flasks and transferred to the graduated glass cylinders of 500 ml. To five of these cylinders califloc A solution at the rate of 2 ppm, 4 ppm, 6 ppm, 8 ppm and 10 ppm was added and one was treated as blank in which the califloc solution was not added. After the transferring of the boiling juice to these cylinders, these were corked and made up side down thrice and then the settling rates were noted the one to which 2 ppm of califloc A was added, gave minimum mud volume as well as higher purity rise and lower colour (Table 1).

A .02% solution of califloc A was prepared

and in further experiments the same solution was used.

In the next experiment one was kept as blank and to the other doses of 2 ppm, 3 ppm, 4 ppm and 5 ppm of califloc A solution were added. The sample to which 3 ppm of the flocculant was added gave less mud volume (Table II).

In the next experiment one was kept as blank and to the others doses of 0.5 ppm, 1 ppm, 2 ppm, 3 ppm and 4 ppm of the califloc A solution were added. The least mud volume was obtained with the sample to which 3 ppm of the califloc A was added (Table III).

Experiment was done in which one was kept as blank and to the others doses of 1 ppm, 2 ppm, 3 ppm and 4 ppm of califloc A were added. The least mud volume was obtained with the one to which 3 ppm of the solution of califloc A was added. The purity rise was also more being 1.05 (Table IV).

In another experiment one was kept as blank and to the others doses of califloc A 1 ppm, 2 ppm and 3 ppm were added. The minimum mud volume was obtained when the califloc A was used at the rate of 3 ppm. (Table V)

Further in order to compare the flocculating ability of the califloc A with Separan AP-30 two experiments were done using 3 ppm of the dose in both the cases and keeping one as blank. In the first experiment, the mud volume was less with using Separan AP-30 and also with the califloc A as compared to the blank. However, the mud volume in case of Separan AP-30 was lesser as compared to that with califloc (table VI).

In the second experiment also the mud volume in the sample in which Separan AP-30 was added was least (table VII).

Conclusion

In the laboratory trials conducted with califloc A it was found that it is effective in making settling rates faster and mud volumes lesser as compared to the blank. The optimum dose of califloc A was determined as 3 ppm. However when compared with the imported Separan AP-30 it was very near to it in flocculating ability although not exactly at par.

Acknowledgement

The authors express their sincere thanks to Dr. N. A. Ramaiah, Director, National Sugar Institute, Kanpur for his interest in this work.

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Table-I

**Raw Juice Brix 15.90, Pol % 13.01, Purity 81.82 Raw Juice Heated to 65°C,
Limed and Sulphited Using 1.8%, Milk of Lime of 12 Be.**

Time in Minutes	Mud volume in mls.					
	Blank	2 ppm	4 ppm	6 ppm	8 ppm	10 ppm
0	500	500	500	500	500	500
5	250	200	205	200	200	205
10	160	150	155	150	150	160
15	142	135	137	134	135	145
20	130	125	128	125	125	133
25	124	115	120	115	117	126
30	117	112	115	114	114	124
60	108	100	105	105	105	112
Analyses of clear supernatant juice						
Brix	15.87	15.81	15.87	15.87	15.77	15.71
Pol	13.18	13.14	14.09	13.14	13.04	13.04
Purity	83.05	83.11	82.48	82.80	82.67	83.00
Purity rise	1.23	1.29	.66	.98	.87	1.18
Colour with red filter	49	48	49	49	49	50

Table II

Raw Juice Brix 15.86, Pol % 13.49, Purity 85.0% Raw Juice was Heated to 65°C, Limed and Sulphited Using 1.8% Milk of Lime of 12 Be.

Time in mts.	Mud Volume in mls.				
	Blank	2 ppm	3 ppm	4 ppm	5 ppm
0	505	505	505	505	505
5	415	330	320	325	320
10	345	232	225	225	230
15	285	210	205	206	210
20	235	198	195	195	200
25	210	185	185	185	187
30	195	182	178	178	180
60	165	158	155	155	158
Analyses of clear supernatant juice					
Brix	15.97	15.81	15.91	15.96	15.94
Pol	13.67	13.58	13.67	13.73	13.73
Purity	85.60	85.90	85.92	86.03	86.14
Purity rise	.54	.84	.86	.97	1.08
Colour with red filter	51	51	51	51	53

Table-III

Raw Juice Brix 15.95, Pol % 13.54, Purity 84.89, Raw Juice Heated to 65°C, Limed and Sulphited Using 1.8%, Milk of Lime 12 Be.

Time in Mts.	Mud Volume in mls.					
	Blank	.5 ppm	1 ppm	2 ppm	3 ppm	4 ppm
0	510	510	510	510	510	510
5	330	240	240	215	215	215
10	215	180	180	175	175	175
15	175	162	163	158	156	156
20	160	150	154	148	146	146
25	150	142	145	140	138	138
30	145	136	140	135	132	132
60	120	118	120	116	115	115
Analyses of clear supernatant juice						
Brix	15.91	15.97	15.91	16.12	15.97	15.96
Pol	13.63	13.63	13.65	13.90	13.63	13.67
Purity	85.67	85.35	85.80	86.23	85.35	85.65
Purity rise	.78	.46	.91	1.34	.46	.76
Colour with red filter	63	63	62	63	63	62

Table—IV**Raw Juice Brix 16.11, Pol % 13.49, Purity 83.74**

Time in Mts.	Mud Volume in mls.				
	Blank	1 ppm	2 ppm	3 ppm	4 ppm
0	500	500	500	500	500
5	435	370	320	295	305
10	375	265	235	225	235
15	290	215	210	205	210
20	250	195	195	190	200
25	225	188	190	185	190
30	210	184	185	176	185
60	175	156	160	152	160
Analyses of clear supernatant juice					
Brix	16.31	16.21	16.22	16.37	16.19
Pol %	13.74	13.69	13.74	13.88	13.71
Purity	84.24	84.45	84.71	84.79	84.68
Purity rise	.50	.71	.97	1.05	.94
Colour with red filter	74	73	72	73	74

Table - V

Raw Juice Brix 16.06, Pol % 13.63, Purity 84.87, Raw Juice Heated to 65°C, Limed and Sulphited Using 1.8%, Milk of Lime 12 Be.

Time in Mts.	Mud Volume in mls.			
	Blank	1 ppm	2 ppm	3 ppm
0	505	505	505	505
5	425	360	360	355
10	350	255	255	250
15	285	230	230	225
20	250	220	215	210
25	225	205	205	198
30	220	200	200	192
60	190	175	175	168
Analyses of clear supernatant juice				
Brix	16.16	16.17	16.07	16.21
Pol n	13.84	13.84	13.78	13.88
Purity	84.64	85.59	85.75	85.63
Purity rise	.77	.72	.88	.76
Colour with red filter	44	44	44	42

Table - VI

Comparative Study of Mud Volume with Blank and with Optimum doses of Separan AP-30 and Califloc A

Time in Mts.	Mud Volume in mls.		
	Blank	With 3 ppm Separan AP-30	With 3 ppm Califloc A
0	500	500	500
2	420	355	365
5	350	280	285
10	250	200	210
15	195	180	188
20	185	165	172
25	170	160	165
30	165	150	155
60	140	125	130

Table-VII

Comparative Study with Optimum doses of Separan AP-30 and Califloc A
Raw Juice Brix 16.27, Pol % = 13.74, Purity 84.45

Time in Mts.	Mud Volume in mls.		
	Blank	With 3 ppm Separan AP-30	With 3 ppm Califloc A
0	500	500	500
3	330	220	235
5	260	185	190
10	170	145	150
15	145	130	135
20	132	116	120
25	125	110	115
30	115	108	112
60	98	90	95
Analyses of clear supernatant juice			
Brix	16.51	16.71	16.49
Pol %	14.03	14.33	14.03
Purity	84.98	85.76	85.08
Purity rise	.53	1.31	.63
Colour with red filter	74	72	72

INVENTORY CONTROL AND COST REDUCTION IN SUGAR INDUSTRY

By

V. Singh

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Introduction :

Cost reduction through better inventory control has assumed significant role not only in Sugar Industry but also in all other Industries. Inventory Control envelopes the entire range of activities which effect the flow, conservation, utilisation, quality and cost of materials. It ensures timely availability of stores and spares for the maintenance of Plant and machinery and manufacture of sugar. It enables us to reduce the inventory cost to bare minimum, while at the same time ensuring that stock cuts do not occur and production does not suffer due to non-availability of any material. The only one motto for a good and efficient inventory Control is that "The right part in the appropriate quantity should be available at the right time at right cost."

How inventory Control Helps in Cost Reduction :

Efficient Inventory Control helps to reduce the cost of production in the following manners :—

(1) Better capacity utilisation :

Timely procurement of good quality spares and stores ensures timely and good overhauling during the off-season and better availability of machinery during the crushing season. These are the two important factors which play important role in effecting better capacity utilisation and thus reducing the cost of production.

(2) Better Recovery :

Timely availability of spares reduces the down time of the machinery and ensures continuous running of the Plant and machinery. This ensures good recovery by way of reduction of losses in the house and better cane management.

(3) Reduction in Maintenance Cost :

Effective Inventory Control ensures full utilisation of man-power and spares and stores. It also helps in getting good material for overhauling at most competitive rates. Timely completion of overhauling eliminates overtime

wages. Maintenance cost is thus reduced by procuring the materials at competitive rates and reducing the cost of labour on repairs.

(4) *Reduction in Inventory Cost :*

Efficient Inventory control reduces the cost of spares and stores in stock at a particular time. Thus the funds are not unnecessarily blocked.

There is a large number of highly sophisticated inventory control systems using Operations Research Techniques and Electronic Data Processing, to suit individual needs of different types of organisations. But in case of sugar industry it is not necessary to adopt very sophisticated methods for the time being. The ordinary ability of the organizational structure should be taken into account while selecting appropriate control system for this industry. Moreover, the following unique factors in this industry also determine the pattern of inventory control.

(1) *The Seasonal Characteristic of the Industry :*

The raw material is available during a limited period and, therefore, maximum capacity utilisation is required to be achieved. Moreover, if there is intermittent working there is fear of diversion of cane towards Gur Khandsari and other neighbouring factories, thus reducing the total production.

Bulk stores like gunny bags, sulphur, lime stone, lubricants, firewood etc. are required only during crushing season and, therefore, their stocks are not required in the off season.

(2) *The Quick Deterioration of Raw Material with the Passage of Time After Harvesting :*

Deterioration of sugarcane takes place after harvesting, more quickly after twenty four hours. It is, therefore, to be ensured that all cane that is purchased, is crushed on any particular day. Down time badly affects not only capacity utilisation but also recovery.

(3) *General overhauling and repairs during the stock season :*

All the major and normal repairs are carried out during slack season. Therefore, most of the materials (stores and spares) for repairs are required during this period.

(4) *Uncertain delivery of some items :*

There are certain items like boiler tubes, brass tubes, iron and steel, shafts of mill rollers, sulphur, gunny bags, steam, coal etc., whose delivery period is not certain. Margin for slippage in delivery should, therefore, be kept in such cases.

(5) *Protected delivery in case of imported spares :*

In some cases, even today, spares are required to be imported. These are delivered after long periods. Therefore, all important spares or components, which are liable to give way, are always kept in stock,

(6) *Capacity of the Workshop :*

Every sugar factory has its own workshop. The capacity to manufacture spares varies from factory to factory. If the workshop can

manufacture a large number of spares, the inventory cost can be considerably reduced.

From the Inventory Control point of view the stores and spares can be classified into the following categories : -

1- Item which are mainly required in the repairs work in the off season :

They are as under :—

- (a) Iron and steel
- (b) Boiler tubes
- (c) Brass tubes
- (d) Non-ferrous materials
- (e) Pipes and pipe fittings
- (f) Ball and roller bearings
- (g) Welding materials
- (h) Machinery spares including electrical spares
- (i) Refractories, and
- (j) Packing and jointings.

These are mainly required during the period from May to September every year. Their requirement should be worked out in the previous off season, tenders should be invited at the appropriate time keeping in view the delivery period and material should be procured in two phases. In first phase the materials should be received in the month of April and in the second phase these should be received in the month of July. This system will eliminate stock-piling of material unnecessarily.

Many of these items are required in small quantities in the crushing season also. Their requirements in the crushing season should be determined on the basis of experience. The importance and the reliability of the material should also be taken into account while deciding the requirement for the crushing season. For the season the maximum and minimum level should be fixed on the basis of experience and judgment. Re-ordering level should also be determined after taking into account the lead time (the time taken from indenting till the materials are actually received), the safety stock level and the rate of consumption. Action should be taken to ensure that the stock in each case does not fall below safety level.

In cases, where there are no requirements in the crushing season, this exercise should not be done and steps should be taken to ensure that practically there is no stock of such items in the crushing season. Many sections of iron and steel, large diameter pipes and pipe fittings, some refractory items etc. may fall within this category.

(2) Items of bulk stores and chemicals required during the crushing season :

The following items fall within this category :—

- (a) Firewood
- (b) Sulphur
- (c) Lime and lime stone
- (d) Filter cloth
- (e) Lubricants

- (f) Coal / coke
- (g) Gunny bags, and
- (h) Furnance oil.

The requirement of these items should also be determined sufficiently in advance say in the month of April each year. The ratio of consumption with respect to cane and total quantity of cane to be crushed should form the basis for determining the consumption. The procurement in all these cases should be staggered. Generally month-wise schedule of procurement should be prepared, taking care that the stock does not fall below safety stock level. Maximum level for crushing season may also be determined so that appropriate steps may be taken when the stock position reaches these levels. These items are not required in the slack season and, therefore, efforts should be made to ensure that there is practically no stock of these items during this period.

In case of items whose delivery in each month is difficult, procurement may be done in one or two phases.

(3) Items of capital nature :

Every year some capital jobs with respect to plant and machinery are done for improving the working of the factory. The requirement of items of stores and machinery for such jobs is not of regular nature. Therefore, separate exercise should be done in such cases. The requirement of such items should be

determined sufficiently in advance and order be placed in time.

(4) Miscellaneous consumable items like Kerosene, Cotton waste, Bolts and Nuts and other similar items :

Similar rule for procurement during the slack and crushing season should be followed in such cases. Their order levels, safety stock levels, maximum and minimum levels etc. should be the same during slack as well as during crushing season.

Reduction of Inventory Cost :

Considerable reduction of inventory costs can be achieved through the following measures :—

(1) A B C Analysis :

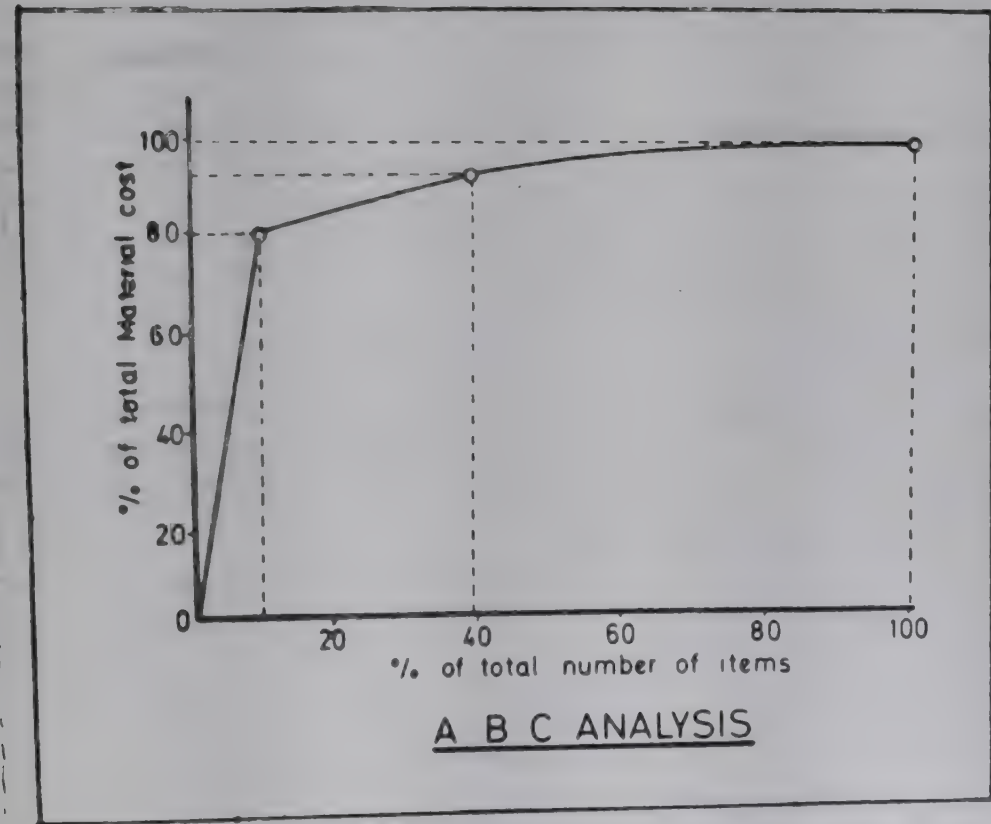
This helps in highlighting, out of a large number of items, the relatively few items of high consumption value on which maximum attention can be focussed and rigorous control measures can be exercised to get the maximum benefits.

In this case the number of units consumed of each item is multiplied by the cost per unit and the items are listed in the descending order of this total consumption cost. The list will indicate that a relatively few items (referred to as 'A' items) will account for a major share of the total cost, say 80% where as the items in 'B' and 'C' category will account for a smaller portion of the total cost.

An illustration is given below, Let us take an analysis of 1000 items costing Rs. 1,00,000 per year.

Classification 1	No. of Items 2	Percentage of total No. of items 3	Total cost in Rupees 4	Percentage of total Cost 5
A	100	10	80,000	80
B	300	30	15,000	15
C	600	60	5,000	5
Total	1,000	100	1,00,000	100

This is graphically represented below :—



If we concentrate our attention to achieve a cost reduction 10% only on 100 'A' items, the net saving will be Rs. 8,000 per year. A cost reduction of 10% on all 600 'C' items will only yield a net saving of Rs. 500/- per year.

(2) Standardization :

It leads to reduction in number and variety of items, thereby resulting in lower inventory cost. Less number of items in larger quantities at lower rates are purchased. This reduces cost of procurement of materials, inventory carrying costs and miscellaneous overheads also.

(3) Determination of the standards for consumption :

The standards for consumption should be correctly fixed on the basis of experience. The reliability of the material should be taken into account.

(4) Reduction of buffer levels :

This can be achieved by reducing lead time by means of proper analysis and selection of suppliers. Reduction of period in paper works and selection of good and quick transport will also help in this direction.

(5) Better material handling :

Prevention of loss due to pilferage, breakage and deterioration in stores should be minimised through better facilities of storage, handling etc.

(6) Preventive maintenance :

This will enable to reduce the number of spares and stores required for maintenance.

(7) Quick disposal of surplus and obsolete materials :

Efforts should be made to prevent the build up of surplus and obsolete materials stocks as far as possible. Action should also be taken to sell the surplus items quickly.

(8) Development and full Utilisation of workshop :

The workshop should be fully developed. All cast iron and non-ferrous castings should be done as far as possible. There should be reasonable number of lathes, planner, shaper, drilling machines and milling machine in the workshop. The personnel of the workshop should be very good in skill.

(9) Value Analysis :

It leads to appreciable savings through substitution of scarce and imported materials by means of cheaper materials serving the same purpose.

(10) Effective control system at all levels.

MINI SUGAR INDUSTRY - SCOPE AND PROSPECTS

By

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ABSTRACT

The Khandsari Sugar Industry, as at present, has been discussed and a new process for the manufacture of Khandsari Sugar is stipulated and the same has been compared with the economics, investment and employment potential of vacuum pan sugar industry. It has been calculated that new Khandsari System is best suited for the development of the country under the existing Socio-Economic conditions.

Introduction

The Janta Party Govt. is keen to promote small scale industries. In a country like India where the unemployment of both the educated and uneducated is a big problem, the small scale industrial sector assumes greater importance. Unlike the large industries, the small scale industries provide higher employment/unit of capacity.

The sugar industry in the country occupies an unique position. It is the largest agro-based industry serving millions of farmers, workers and petty shopkeepers. The village economy gets directly affected with the state of affairs in the sugar industry.

Historically India is the home of sugar-cane and sugar, in one form or the other, is made here from the times immemorial. But

the organised vacuum pan industry was established in the country not earlier than 50 years. The original size of sugar mills was 300 to 500 tonnes of cane/day but with the introduction and progressive increase in Government controls on various activities of this Industry, the tendency to increase the capacity of the factories grew in order to reduce the cost of conversion per unit of production and thus increase the profits.

Now the sugar factories of 500 to 6000 tonnes cane/day are existing, the smaller ones are facing difficulty in making both ends meet and struggling for existence, thanks to the policy of zonal averages for fixation of different controls.

Existence of very large sized units in few

foreign countries is cited as an argument in favour of the larger units. The large sugar units are also claimed to be more efficient although size has no direct relevancy to efficiency. But the exponents of larger sugar units forget that the Socio-Economic conditions in our country are different and demand efficient but more employment oriented industries

Fortunately for the country, the sugar industry co-exists in large, small and cottage levels. The cottage sugar industry i. e. gur making is most ancient in character and provides self employment to the cane grower and his family. As compared to others, the production of sugar (Gur) is too wasteful to retain it. Also with the knowledge of the new techniques of farm operation, the farmer is gainfully employed on his farms for almost alround the year, and thus has little time to spare for Gur manufacture. With the increasing educational facilities in villages, his children are schooling and he does not have surplus family hands to work on his cane crushing operation for gur manufacture. Thus the ancient wasteful gur manufacturing cottage industry is destined to vanish sooner than expected.

Small Scale Sector

The Janta Party Govt. realising the importance of the small scale sector under the existing Socio-Economic conditions in the country, has decided (as reported in the Press) to promote the sugar industry in small scale sector only. The small scale sector sugar industry as it exists today is the Sulphitation Khandsari Industry and so, it needs study and also scope for its progress.

The Sulphitation Khandsari Industry Process in Brief

The cane is crushed dry in six roller hydraulic crusher extracting juice to the extent of 80 to 82%. The juice is limed and sulphited in batch manner and then heated to boiling before settling. The decanted clarified juice which is free from most of the suspended matter is concentrated in multi-pan (usually six) bels to 82-84° Bx. and crystallised by cooling. The rab thus produced is centrifuged to obtain I sugar; the molasses is reboiled to get II & III Sugars. The total recovery of sugar is 7 to 7.5% cane, out of which only about 5% is fit for direct consumption.

The Gap

If the same cane is milled in a vacuum pan Sugar Factory the Sugar recovery will be about 9.0% and all this sugar will be fit for direct consumption. Hence, there is a wide gap between the extraction and quality of sugar obtainable in vacuum pan and the Sulphitation Khandsari Industries. How to bridge this gap in order to make the Khandsari Sugar Industry more attractive and comparable with respect to sugar recovery and its quality.

The Loss of Sugar

The maximum sugar loss in Khandsari Industry takes place in milling. Six rollers or seldom 9 rollers are used for juice extraction and dry milling is done. 82% of juice is extracted whereas 95% of juice can be extracted in the wet milling. Thus about 13% of recoverable juice is lost which amounts to above 1% of sugar recovery on cane basis. Above 0.5% of sugar recovery is

lost due to inversion and caremelisation, and yet another 0.5% extra recovery is lost in molasses. Thus the sugar recovery of sulphitation Khandsari sugar is lower by about 2%

The Fuel

The Sulphitation Khandsari Sugar Indus-

try as a rule falls short of fuel i.e. Cane Bagasse and has to supplement it by fire wood etc. The shortage of fuel is the main reason that the Khandsari Industry has not been able to adopt the efficient wet milling for sugarcane as is done in vacuum pan industry.

Scope for development

The technique of extraction of 95% of juice being known (wet milling), the main problem of the Khandsari Industry boils down to the problem of efficient use of fuel.

The calofific value of bagasse :—

Dry bagasse 8280 B. Th. U/lb

Wet bagasse 4040 „ „

Fuel Balance

Crushing of cane	...	100 lbs.
Juice extracted	...	68 „
Bagasse „	...	32 „
Water in bagasse @ 48%	...	15.4 lbs.
Fibre in bagasse	...	16.6 lbs.
Calorific value dry basis (A)	...	137448 B, Th. U.
Calorific value wet	..	125240 B. Th. U.

Heat Requirement

Heating of juice (sulphitation bel) (58°F to 213°F)		9480 B. Th. U.
1st Rab boiling	...	50800 B. Th. U.
II & 3rd rab boiling	..	4000 „
Total	...	<u>64280 „</u>

Extra fuel generally used as wood 5 % cane	...	5 lbs.
Calorific value of dry wood	..	7650 B. Th. U.
Heat available (B)	...	38250 B. Th. U.
Total heat provided (A+B)	...	175698 B. Th. U.
Heat utilisation	...	About 36 %

If the extraction of juice is increased to 94–25% by utilising 12 roller Milling Plant with compound maceration upto 20% cane and screw press for de-watering upto 40–42% moisture, the heat requirement in process will be as follows :—(Raw juice % cane- 90)

1. Juice heating	...	12,555 B. Th. U.
2. 1st Rab boiling	...	75,670 „
3. 2nd or 3rd Rab	...	5,000 „

		93,225 „

Extra fuel demand at the existing level of heat utilisation (i.e. 36%)	...	16% as Dry wood.
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Thus it is seen that in case the extraction of juice is increased, the extra fuel demand will be as high as 16% cane as wood.

Heat Economy Measures

The waste of heat takes place through the flue gases. Fuel efficiency can be increased by partial recovery of heat from the flue gases. The author had invented successfully a tubular wastage heat recovery unit. The unit consists of an inclined tube bank connected to a drum at the discharge end. The juice entering the feed chamber passes through the tubes to the drum from where it overflows to the

Bel. The waste heat gases circulate outside the tubes before passing to the chimney. The juice boils in the tubes and it has been found that 30–33% evaporation of juice is obtained. Hence heat recovered from waste gases–32,020 B. Th. U.

Further heat economy can be affected by adopting juice heaters for heating the juice utilising the vapours pooled together from the waste heat recovery units. The vapours are capable of heating the juice upto 90°C. Thus the further heat economy obtained will be as—

$$90 \times .9 \times 137 = 11097 \text{ or say } 11,100 \text{ B. Th. U.}$$

$$\text{Hence Total heat economy} = 32020 + 11,100 = 43,120 \text{ B. Th. U.}$$

$$\text{Total heat required from bagasse} = 93225 - 43120$$

$$50105 \text{ B. Th. U.}$$

$$\text{Heat available at the present level of furnace efficiency} - 137448 \times .36 = 48,880 \text{ B. Th. U.}$$

$$\text{Hence shortfall in heat} = 50105 - 48880$$

$$= 1225 \text{ B. Th. U. or less than } 0.5\% \text{ of extra fuel}$$

This small short fall of 1225 B. Th. U. can be made good by utilising continuous juice clarifier (already in use) instead of the Settling Tanks. The clarified juice temperature can be obtained 90°C instead of $55-60^{\circ}\text{C}$ as at present as the Juice Clarifier can be properly insulated. The heat economy advantage on this account can be about 4370 B. Th. U. Hence a good fuel balance strikes.

Thus the utilisation of heat can be increased from the present level of 36% to about 68%.

The following conclusions can be drawn from the above discussion that -

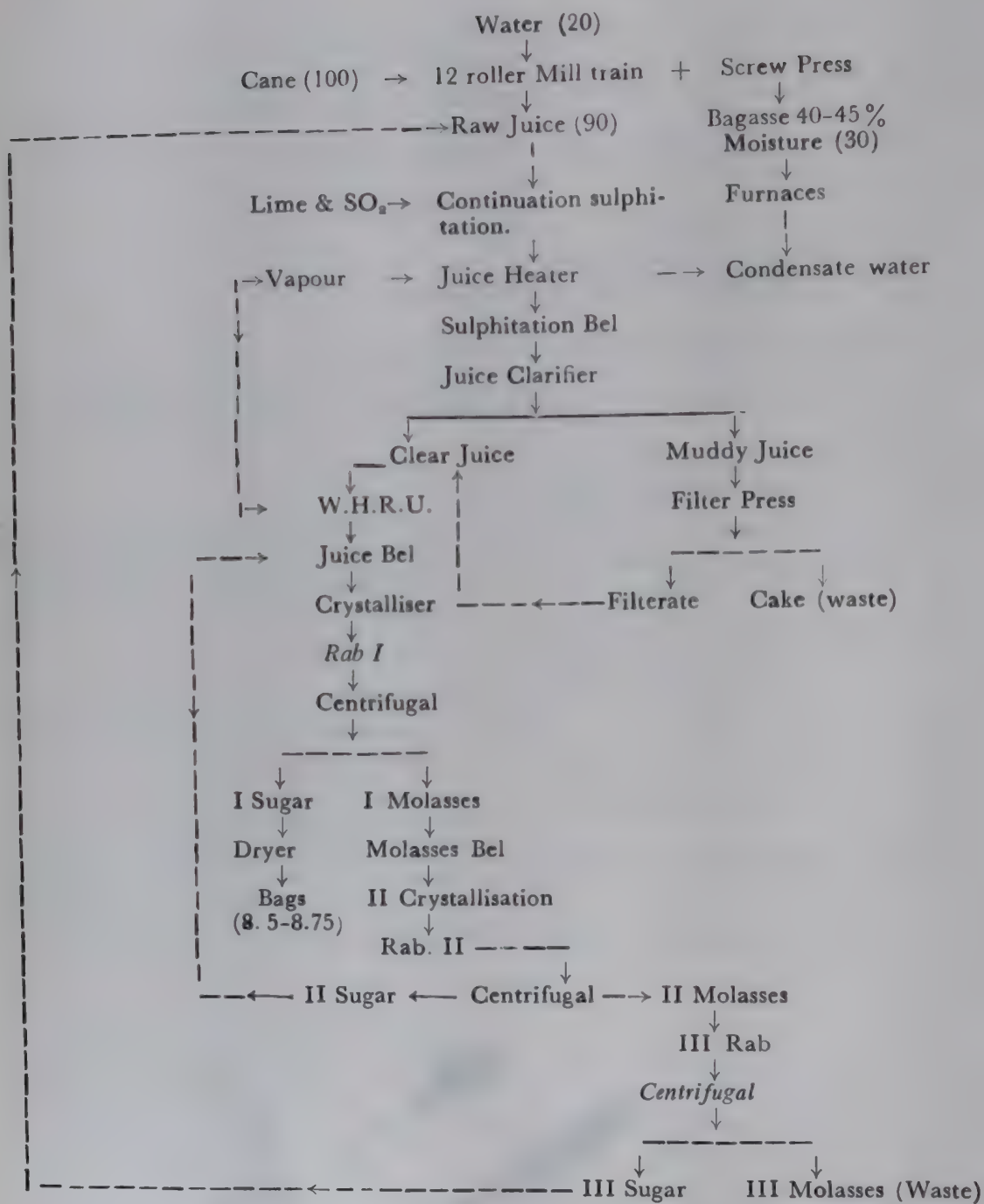
1. There is scope of improving the heat

utilisation by about 30-32%.

2. There is scope for increasing the extraction of juice from 80-82% to 94-95% as in Sugar Mills by adopting 12 roller milling train and a screw press for Bagasse de-watering.
3. The quicker boiling in waste heat recovery units is likely to reduce the burning losses.

Hence the recovery of sugar can be increased from 7-7.5 to 8.5-8.75%.

The process that emerges now for the Khandasary Industry is as given below : -



The Khandsari factories using 13"×18" and 16"×24" six roller crusher (Dry milling) and the proposed 4 mill tandem of 13"×18" can be compared as follows :—

I. Fixed Assets

Sl. No.	Particulars	13"×18" Six Roller	16"×24" Six Roller	13"×18" Twelve Roller with Screw Press
1.	Crushing/day tons	100	200	150
2.	Land & Building	4.00 Lacs	5.50 Lacs	4.50 Lacs
3.	Plant & Machinery	8.00 „	13.50 „	12.50 „
4.	Pre-operating Exp.	0 25 „	0 25 „	0.25 „
Total fixed Assets		12 25	19.25	17.25

II. Annual Working Expenses (150 days season)

Sl. No.	Particulars	Qnty.	Amount Rs. Lacs	Qnty.	Amount Rs. Lacs	Qnty.	Amount Rs. Lacs
1.	Cane M. T.	15000	18.00	30000	36.00	22500	27.00
2.	Lime 0.25% cane	37.5	0.15	75.0	0.30	56.25	0.23
3.	Sulphur	12.0	0.18	24.0	0.36	18.00	0.27
4.	Castor seed etc.		0.06		0.12		0.09
5.	Gunny bags	11250	0.56	22500	1.12	19700	0.98
6.	Filter cloth		0.08		0.14		0.10
7.	Lubricants etc.		0.08		0.10		0.15
8.	Miscellaneous		0.25		0.25		0.25

Contd...

Sl. No.	Particulars	Qty.	Amount Rs. Lacs	Qty.	Amount Rs. Lacs	Qty.	Amount Rs. Lacs
9.	Salary & Wages						
a)	Yearly staff	11	0.50	11	0.50	11	0.50
b)	Seasonal skilled	30	0.60	40	0.80	30	0.60
c)	Unskilled	150	1.25	220	1.80	150	1.25
10.	Power H. P.	160	0.90	275	1.50	250	1.40
11.	Extra fuel		1.00		1.60		—
12.	Repair & Renewal		0.25		00.40		0.40
13.	Excise duty		1.30		2.60		2.15
14.	Cane Purchase tax		1.50		3.00		2.25
			26.66		50.59		37.62
Sales Proceeds							
	Grade I @ 320/-	7500	24.00	15000	48.00	19125	61.20
	per qntl.	(5%)		(5%)		(8.5%)	
	Grade II @ Rs. 240/-	Q1.	2550	5100	12.24	—	—
		(1.7%)		(1.7%)			
	Grade III @ Rs. 150/-	Q1.	1200	2400	3.68	—	—
		(0.8%)		(0.8%)			
	Molasses @ Rs. 5/	Q1.	6000	16000	0.60	11250	0.56
		(4%)		(4%)		(5%)	
	Total	...	32.10		64.20		61.76

Contd ..

Gross Profit	5.44	13.61	24.14
Less interest	1.75	3.00	2.50
Depreciation	1.00	1.50	1.50
	2.75	4.50	4.00
NET PROFIT	2.69	9.11	20.14

Thus the profitability of the improved Khandsari Plant increases so much so that it can afford to pay—

- (a) Higher can price
- (b) Higher excise duty
- (c) Higher wages.

Vacuum in Mini Sugar Mill

There is a cry from some quarters for the introduction of vacuum in small sugar mills but treating them at par with Khandsari Industry with regard to levies and taxation etc.

The investment in a 150 T. C. D. Mini

Sugar Mill using vacuum boiling will be about Rupees Eighty Lacs (Rs. 80,00,000). The running expenses will also be more as highly skilled men will have to be employed. Even if, such an industry is treated at par with the Khandsari Industry, the economies will be found highly negative. As a matter of fact, it will be just putting the clock back by 50 years or so. Such units will also be, as a rule, deficient in fuel.

By introducing vacuum in Khandsari industry, it will defeat the very purpose of creating capacity at reduced cost with increased employment opportunity. The comparative figures are given below :

	150 TCD Modern Khandsari Plant	150 TCD Vac. Pan Khandsari Plant	1250 TCD Vac. Pan Sugar Plant
Capacity TCD	150	150	1250
Capital Investment (Lacs)	17.25	80.00	600.00
„ „ per one ton of capacity	0.115	0.533	0.48
Employment Opportunity	200	120	800
Employment/One lac investment.	11.6	1.50	1.33

Conclusion

The Khandsari Industry with some improvement in fuel economy and milling techniques, without changing its basic character i. e. without the introduction of vacuum, has great scope for progress and has the potential to

yield good quality direct consumption sugar with higher sugar recovery. Development of the small scale sugar industry can bring more employment, less capital investment and a quicker change in Socio-economic conditions of the country side.

STUDIES OF THE USE OF FLOCCULATING AGENTS DURING SUGARCANE JUICE CLARIFICATION PART XI—SETTLING STUDIES WITH CALIFLOC-A

By

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ABSTRACT

The flocculating efficiency of an indigenous flocculant namely Califloc A was tested with limed and sulphited juice in the laboratory. The optimum dose of the flocculant was found to be 2 ppm. which increases the settling rate to about 3 times as compared with blank. A comparison of the flocculant with Tulsepar A-30 and 1-40 revealed that the performance of Califloc-A was better in respect of settling rate and final mud volume.

Introduction

Many times the sugar factories have to face settling difficulties in the clarification stage resulting in the formation of thin muds, due to which crushing rate is seriously affected. Sometimes these difficulties may be overcome by good liming control, efficient mixing of lime with raw juice, adequate adjustment of phosphate content in juice, or maintenance of constant temperature of juice entering the continuous subsider etc. Efficient control of the factory processes may not always result in solving the difficulties of settling station especially when juices of refractory nature and being processed. In such cases, recourse may had to the polyelectrolyte treat-

ment which results in large flocs with quick, settling characteristic. A number of flocculating agents, which are mostly polyelectrolytic in nature have been used by several workers as aids to settling during sugarcane juice clarification. These flocculating agents are effective in very small doses. The trial of separan AP-30 as a flocculating agent was conducted by the authors on laboratory scale as well as on factory scale both in Khandsari² and vacumm pan³⁻⁷ sugar manufacture, and it was recorded that the use of this flocculating agent gave satisfactory results. Other flocculating agents that have been successfully used by the authors in clarification of cane juice at

laboratory scale are Flocbel FC-160, FC-170, FC-180⁸, Tulsepar A-30, A-40, Floxin-10, Boze Flock A51BT, A61BT⁹ Prima flock A-10, Morarfloc A-40H, Dedenol O. T. and Hy-flock¹⁰. Linear polymers derived from acrylamide with molecular weights greater than 300,000 have been found to be of great use¹¹. In contrast to the acrylic polymers the non-ionic polyethylene oxide¹² polymers have been mentioned as useful water-soluble flocculating agents. Many miscellaneous polymeric materials have been claimed to be of utility in the sugar industry as flocculants. Among these are included alkylene dichloride-alkylene polyamine polycondensation polymers and their cross-linked derivatives¹³. One interesting polymer claimed in the clarification of cane sugar juice is liquid polyorganosiloxane. These polymers are said to aggregate and settle the floc when added before the normal precipitating chemicals¹⁴.

Recently a sample of new flocculating agent namely Califloc-A, an anionic polymeric solution in water having 50% solid contents, was made available to us by the manufacturer Calico Chemicals Plastics and Fibres Division, Bombay. The present investigation was therefore undertaken to study its effect on settling of limed and sulphited juice in the laboratory and also to compare their flocculating abilities with Tulsepar A-30 and A-40.

A 0.05% solution of the flocculating agents under study was prepared according to the procedure already described. Limed and sulphited juice of pH 7.1-7.2 was obtained from Experimental Sugar Factory attached to this Institute (crushing season 1977-78). 500 ml portions of the juice were placed in each

of the six beakers and heated to boiling on hot plate. No flocculating agent was added to the first beaker which served as blank. To the boiling juice of other beakers different doses of flocculating agent corresponding to 2, 4, 6, 8, and 10 ppm were added drop by drop and the mixture was gently stirred. After mixing, the contents of the beakers were quickly transferred to glass stoppered measuring cylinders and the liquid level in each was made upto the 500 ml mark by the addition of boiled distilled water. The contents of the cylinders were mixed gently and the mud was allowed to settle. The volume of settling precipitate was noted after definite interval of time. Results of the settling trial with Califloc-A are recorded in Table 1. A comparison of this flocculating agent is given in table 2.

It is observed that the mud volume recorded by the blank after 30 minutes is attained by the use of Califloc A (Table 1) in 10 and 15 minutes when the flocculant was used in a dose of 2-4 ppm and 6-10 ppm respectively. Thus it is demonstrated that the flocculant increases the settling rate to about 3 times when it is used in a minimum dose of 2 ppm. The final mud volume after one hour in the sample containing 2 ppm Califloc-A is 190 ml against 230 ml in the case of blank. This indicates that a decrease in mud volume to the extent of 17% has occurred as a result of treatment of the juice with Califloc-A.

Table 2 records the comparative data when Califloc-A, Tulsepar A-30 and A-40 were used in more or less in their optimum doses.

The results as depicted in Fig. 1 point out that Califloc-A gives the best settling effect

when it is used in an optimum dose of 2 ppm. After 5 minutes the mud volume with the use of Califloc-A (2 ppm) and Tulsepar A-40 (4 ppm) is 260 ml and 300 ml respectively as against 440 ml in case of blank. Similarly after 15 minutes of settling the mud volume in case of Califloc-A and Tulsepar A 40 is 165 and 200 respectively as against 350 ml in case of blank. It is also observed that the blank sample after 60 minutes shows a mud volume of 190 ml and the use of Califloc-A gives the same mud volume as in the case of

blank in 10 minutes only so the performance of Califloc-A appears to be the best in respect of settling rate and final mud volume, when it is used in an optimum dose of 2 ppm.

Acknowledgement

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Table-1

Settling Studies With Different doses of Califloc-A

Time in minutes	Mud volume in ml.					
	Blank	2 ppm	4 ppm	6 ppm	8 ppm	10 ppm
5	450	305	325	375	325	340
10	385	265	270	290	275	280
15	340	240	250	260	250	255
20	310	220	240	250	230	240
25	280	215	230	240	225	225
30	260	210	225	235	215	220
35	250	200	220	225	205	210
40	240	195	215	220	200	205
45	240	195	210	210	200	205
50	235	190	205	210	195	200
55	235	190	205	210	195	200
60	230	190	205	210	195	195

Table—2.

**A Comparison of Flocculating Effeciencies of Califloc-A,
Tulsepar A-30 and Tulsepar A-40**

Time in minutes	Mud volume in ml					
	Blank	Califloc A 2 ppm	Califloc A 4 ppm	Tul A 30 4 ppm	Tul A 40 2 ppm	Tul A 40 4 ppm
5	440	260	285	375	365	300
10	380	190	210	290	300	225
15	350	165	185	250	245	200
20	325	155	170	210	215	185
25	285	150	165	195	200	175
30	270	145	160	190	190	170
35	250	140	155	185	185	165
40	225	140	150	180	110	165
45	200	135	150	175	175	165
50	190	135	150	175	175	160
55	190	135	145	170	175	160
60	190	135	145	165	170	155

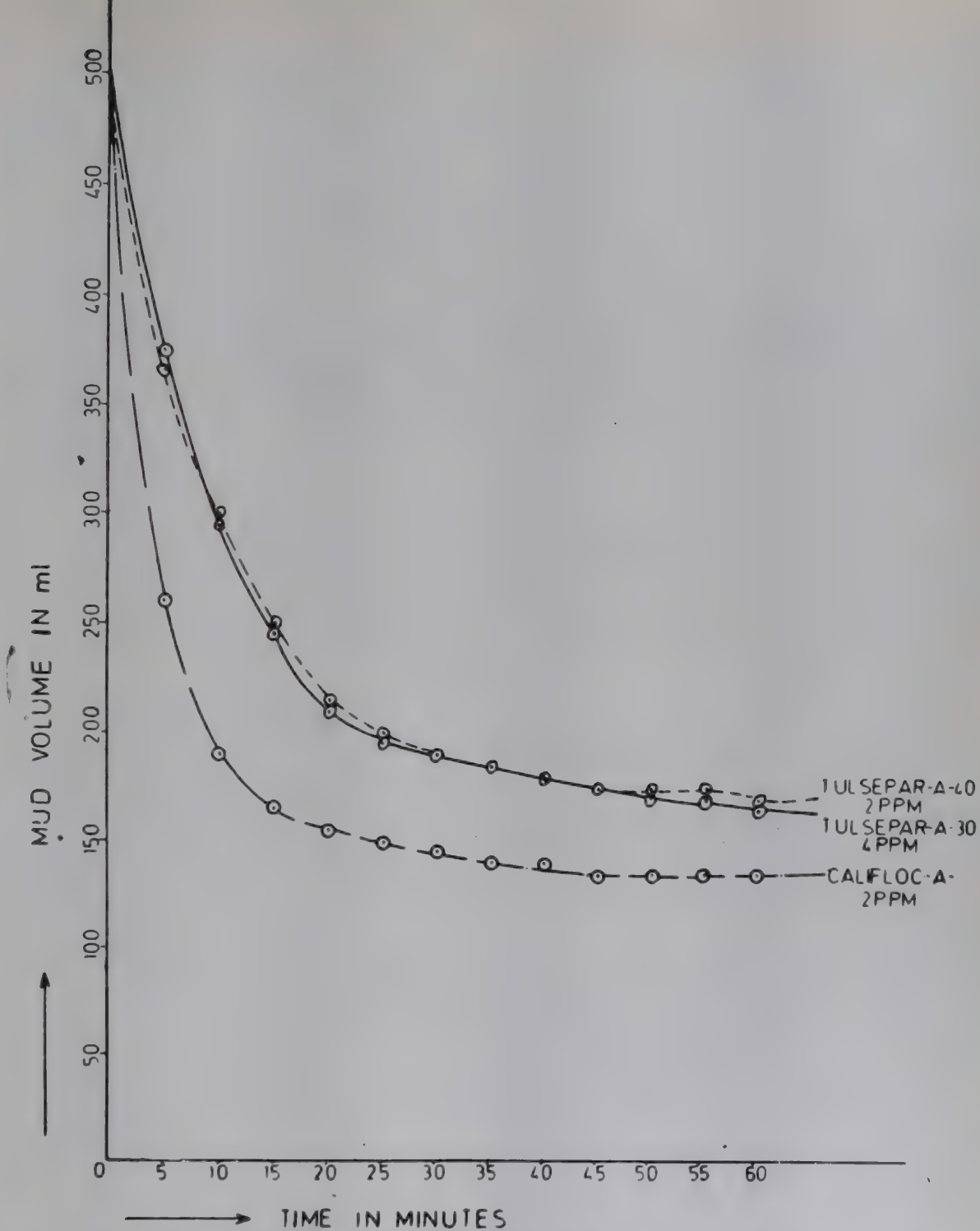


FIG1- FLOCCULATING EFFECIENCIES OF CALIFLOC-A, TULSEPAR-A-30 AND TULSEPAR-A-40

MILL PERFORMANCE — A COMPARATIVE STUDY FOR COMPAIRING THE TECHNICAL PERFORMANCE INDEPENDENT OF SUCROSE CONTENT IN CANE :

By

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ABSTRACT

There is a general confusion at present in attempts to compare or judge the technical efficiency of a milling tandem. Most commonly used criterion of reduced mill extraction actually does not give any idea of Mill's technical efficiency. The reduced mill extraction as calculated on the basis of 'Hugot' and 'Mittal' expression is highly dependent on sucrose content of cane and is quite misleading as a measure of technical efficiency of mills. In the present article an alternate proposal has been given for such an expression to compare technical efficiency of mills independent of sucrose content in cane.

It is widely known that the current reduced mill extraction used in the above evaluation results in even inefficient mills getting easily through the fixed criterion when sucrose content is high (for example Maharashtra) and even efficient mills not managing to meet the criterion when the sucrose content is low (for example below 9% or so in start or end of season or in Bihar etc.).

-
- I The Industry is popularly using Reduced Mill Extraction as a measure of the Mill efficiency.
 - II The reduced Mill extraction is derived from an expression which is expected to eliminate the effect of the sucrose content in cane and the fibre content of cane.

'Hogot' defines :

$$\text{A. Extraction} = \frac{\text{Sucrose or pol\% in mixed juice \% cane (X)}}{\text{Sucrosse or pol \% cane (Y)}} \times 100$$

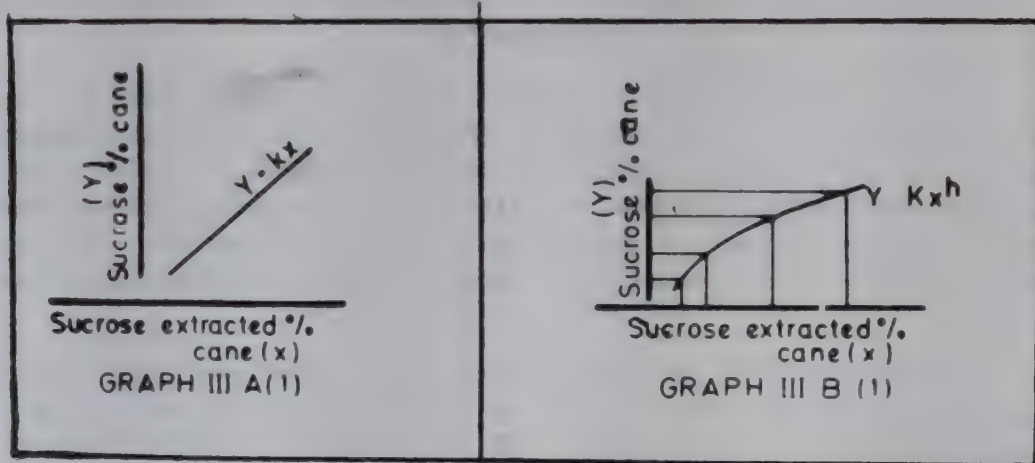
He clarifies that this expression expresses the commercial rather than the technical efficiency of equipment.

- (B) Hugot also mentions that sugar extracted is closely proportional, other things being constant to the sugar content of cane. This expression has the advantage of eliminating at least theoretically the factor for sucrose content in cane.

This assumption seems to be contrary to observation and of course, no theoretical basis for this exists. It is well known that if we presume, say

15% of a given item in a matrix, it is easier to extract say 90% of this item than to extract the same percentage out of a matrix where only 3% of the matrix to all other things being equal. A typical example is ore separation.

Practically, other things being equal, we find that even for some fibre (after compensating for fibre factor as per BL Mittal or Noel Deerr) and same set of mills the RME is quite different for cane with sucrose content of say 14 as compared with 8. The variation practically is as high as 94 RME compared to 89.



III

- (A) Hough has presumed there is a linear relation between sucrose in cane and sucrose extracted % cane as shown in graph III A (i)

K is a constant. It is clear that for any sucrose content, the extraction is proportional to sucrose in cane.

- III (B) The author proposes that the relation is not linear but as shown in graph III B (i)

The graph shows that it is easier to extract sucrose out of a high sucrose cane than a lower.

e. g. For an increase of sucrose one unit from 7-8 the sucrose extracted will be lower than for an increase of sucrose from 14-15. Here k is a constant. n is another constant or variable.

- IV The author tried to collect some data on extraction under similar conditions for different sucrose canes. Admittedly the data collection has been very little and the results, to that extent, are strictly an approximation. This can be made more exact by further empirical study. It is needed to plot the graph III B (I) with different set of authentic data and find out the value of 'n'. This can be done by either of two methods analytical or graphical (both are recommended and the best mean is to be taken).

(A) Analytical

The sucrose y and x along with Mill extraction (compensated for fibre at 12.5) may be tabulated.

$$y = Kx^n$$

We make first presumption that over the restricted range of sucrose, say 7 to 15, the 'n' is constant. Now for different y & x (both are known, we find out 'n').

$$\text{e. g. } y_1 = Kx_1^n$$

$$y_2 = Kx_2^n$$

$$\frac{y_1}{y_2} = \left(\frac{x_1}{x_2} \right)^n$$

Now by iteration 'n' can be found. Different values of 'n' will be obtained for y_3, y_4 etc. and mean can be taken.

(B) Graphical

We may plot a number of curves with $n = 0.6, 0.7, 0.8, 0.9, 1.0$ etc. This may be compared with the actual plot of $y = Kx^n$. The one suiting most adequately may be then further refined and the 'n' for most closely matching curve may be used.

- V By analytical method, the author arrived at a figure of 'n' as 0.91 as the first approximation.
- VI Now we find an extraction called Mill Extraction (SA).

SA = Sucrose adjusted.

This will be obtained by

$$x \text{ Adjusted} = x^{0.91}.$$

$$\text{Mill extraction (SA)} = \frac{x^{0.91}}{y} \times 100$$

x = Sucrose % extracted in MJ % cane.

y = Sucrose % cane.

VII Further corrections for fibre may be made in the usual fashion by Noel Deerr or B. L. Mittal — fibre correction expression.

Note :—The multiplying factor should be obtained as explained below :

$$e'_{12.5} = \frac{0.125 (1 - e)}{f} \quad \begin{array}{l} \text{(B. L. Mittal} \\ \text{R. M. E. expression} \\ \text{Reference Hugot)} \end{array}$$

where $e'_{12.5}$ = Reduced Mill extraction at 12.5% fibre adjusted.

f = Fibre % in the cane in question

e = The extraction obtained with cane of fibre 'f',

To find out RME (SA) We use the expression

$$\text{RME (SA)} = \frac{\text{ME (SA)} \times e'_{12.5}}{e}$$

EXAMPLE :

Case I :

Sucrose = 14% in cane

Extraction. (e) = 94

Sucrose in MJ % cane = 13.16 %

Fibre (f) = 14%

$$\text{ME (SA)} = \frac{(13.16)^{0.91}}{14} \times 100$$

$$= 74.4$$

$$e'_{12.5} = 1 - \frac{0.125 (1 - .94)}{0.14}$$

$$\begin{aligned}
 &= 1 - \frac{0.125 \times 0.06}{0.94} \\
 &= 1 - 0.05 \\
 \text{RME} &= 95\% \\
 \text{RME (SA)} &= \frac{74.4 \times 0.95}{0.94} \\
 \text{RME (SA)} &= 75.19 \\
 \text{RME (SA)}_M &= 94.74 \quad \text{— see note.}
 \end{aligned}$$

Case 2 :

$$\begin{aligned}
 \text{Sucrose} &= 9\% \text{ in cane} \\
 \text{Extraction (e)} &= 90\% \\
 \text{Sucrose ni MJ \% cane} &= 8.1 \\
 \text{Fibre (f)} &= 14\% \\
 \text{ME (SA)} &= \frac{(8.1)^{0.91}}{9} \times 100 \\
 \text{ME (SA)} &= 74.6 \\
 c'_{12.5} &= 1 - \frac{0.125 (1 - 0.90)}{0.14} \\
 &= 1 - \frac{0.125 \times 0.1}{0.14} \\
 &= 1 - 0.09 \\
 c'_{12.5} &= 91\% \\
 \text{RME (SA)} &= \frac{74.6 \times 0.91}{0.90} \\
 \text{RME (SA)} &= 75.4 \\
 \text{RME (SA)}_M &= 95.0
 \end{aligned}$$

Note : The extraction figures of around 75 will be quite confusing and strictly for making them less offensive we can use a multiplier factor of 1.26.

This is strictly to make them appealing and has no rational basis mathematically or scientifically. The basic presumption that technical performance cannot be judged by commercial efficiency due to non-linear nature of cane sucrose extractability effectively bars any such absolute attempt.

- VIII The above will be RME (SA) which will be a measure of technical efficiency of mills and *not* commercial efficiency.
- IX It will be possible to use RME (SA) for the purposes of performance trials, judging the various competitive equipments available etc. It may be clearly understood that the percentage figures obtained are not an indication of physical extraction but a measure of technical performance of equipment.

Acknowledgement

Grateful acknowledgements are due to inspiration from Mr. S. C. Jolly. (Manager, Sugar Machinery Division, ISGEC) and Additional General Manager—SSM.

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PROSPECTS OF REDUCTION IN COST OF PRODUCTION OF SUGAR IN INDIA—SOME PRACTICAL ASPECTS

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ABSTRACT

Despite being largest producer of sugarcane and third largest producer of cane sugar in the world, India stands far behind in terms of yield of sugarcane and sugar per ha, which along with un-economic working conditions poses a danger to the economic viability of this important industry of the country. Science and Technology coupled with modern techniques of Management have pivotal roles in transforming this state of sugar industry into promising centres of dynamic agro-industrial base by affording means for a drastic reduction in the production cost bringing it at competitive levels with other sugar producing countries of the World. It is all the more essential at this stage, because what to say of international market, with the gloomy internal market conditions prevailing now the factories cannot exist viably with a lavish production cost. Various factors which directly influence the cost of production have been discussed in brief and suggestions have been made for improvement. Due emphasis has been given to the need of intensified cane development having inherent potential and scope for improving productivity. Implementation of other measures like Modernisation, Preventive Maintenance, Inventory Control, Capacity Expansion etc., will improve efficiencies, reduce unproductive labour cost, decrease consumptions thereby achieving a better cost structure with the basic aim of producing cheaper sugar, which alone can bring profitability and hence prosperity in the areas of its operation.

Back Ground

Indian Sugar Industry, being a premier agro-based industry ranking second only to cotton textiles, occupies an important position in the Industrial map of the country. Having close links with the rural economy, it has an

unique role in the national economy with potential for transmitting the industrial impulses to the rural areas. Indian sugar Industry, having a distinctive history of 45 years, however, presents a mixed picture at present. There are areas where the productivity in the farm and factory have touched peaks while

there are regions where the industry is severely hit by problems like, low yield, uneconomic sizes, low efficiencies & high losses in production. A dispassionate analysis will reveal that unplanned growth of industry without keeping a fairly conceived scope for future expansion and modernisation coupled with wide fluctuations in the production is primarily responsible for such disparities. These disparities exist more in Northern India especially sub-tropical regions of East U. P. and Bihar as compared to South and Maharashtra. Following the grant of protection to sugar Industry in 1932, a large number of small sugar factories came into existence mostly in U. P. & Bihar as this area was rich in sugar cane. These plants of very low installed capacity having no foresight or planning for any scope of their future expansion or modernisation were clustered in the areas of cane availability with out-moded and inefficient processing equipments yielding very low working efficiencies and high production cost posing a serious question to their economic viability in the present days. We may be proud of the fact that India is the largest producer of sugar cane in the World but in terms of yields of sugar cane and sugar per unit area, processing cost of sugar, we stand almost at the lowest rung of the ladder as the sugar produced in India is among the costliest in the World. It is perhaps due to this reason that inspite of being largest producer of sugarcane, India ranks third in the production of cane sugar standing next to Brazil & Cuba because what to say of competing with sugar from other sugar producing countries in the international market, we are unable to give a fair competition to parallel cottage industries of Gur & Khandsari utilizing sugarcane as raw material. With the

passage of time, with all round spiralling prices, the situation is getting worse with increasing cost of repairs, maintenance and replacements & even so with uncertainties as to the performance, the present cost structure of Indian Sugar Industry needs a complete reshaping. Science & Technology coupled with modern techniques of Management have pivotal role in transforming this state of affairs of the sugar industry into promising centres of dynamic agro-industrial base which essentially calls for a drastic reduction in the cost of production bringing it at the competitive levels with other sugar producing countries in the international market which will ultimately bring profitability and hence prosperity in its area of operation.

Factors Influencing Cost of Production

As a general classification, sugar factories work with two kinds of costs e. g. (a) Fixed costs (b) variable costs. The costs which are non-variant with volume viz. administrative staff charges, salaries & wages to permanent employees, depreciation on machinery, interest on long term loans etc. form fixed costs while cost of raw material, cost of consumable stores, machinery spare parts required for repairs and maintenance, processing chemicals, packing material salaries and wages to the seasonal employees fall in the class of variable costs. Therefore, any attempt aimed at sizable reduction in the cost of production would essentially require:-

(i) Reduction in its fixed or variable cost by introducing modern Management Practices.

(ii) Quantity of finished products is

increased by improving the quality of raw material and minimising total losses during manufacture by employing better processing techniques and equipment incorporating modern technological advances. The degree to which above two measures are implemented in practice will decide the success in cost reduction. To be more elaborate, a systematic approach to reduce the production cost of sugar would essentially consist of following elements.

(1) Availability and quality of raw material i. e. sugarcane has to be improved.

(2) Processing technique employed for the manufacture of sugar to incorporate modern technology which must ensure :

(a) Maximum extraction at Mill House & Boiling House, minimum circulation of sugar & non-sugars in the Boiling House which would automatically minimise total losses during manufacture.

(b) Fuel & Power economy

(c) Continuity in operation to be preferred at every stage with proper instrumentation at every stage which would yield homogeneous product on one hand & would curtail unproductive labour force, improving the economy of the project, which is undesireably poor at present.

(3) Improved preventive maintenance.

(4) Reduction in stores consumption,

efficient inventory controls by application of modern techniques of Material Management.

(5) Effective utilization of Bye-products.

(6) Expansion of installed capacity to the level of economic viability.

1. Improvements in Availability and Quality of Sugarcane

Nearly two third of our sugar cost (excluding excise) is the cost of sugar cane, the raw material which requires quite careful & planned handling in the fields while it matures. It is a popular axiom that "Sugar is produced in the fields" & sometimes back it was rightly stated by Gundu Rao that "The battle for reducing the cost of sugar production has to be fought in the sugar cane fields". Intensified and vigorous sugar cane development work, is fundamental to the growth of the industry. Higher productivity of sugarcane both in terms of quantity and sugar per ha is the urgent need of the time because there hardly exists any scope of a further increase in the area under sugarcane and any increase in demand would have to be met by way of higher yields only. Moreover, higher productivity in the fields would reduce the present high cost of production of sugarcane and a stage may come when even lower cane price would appeal to the cane grower as remunerative. It is a painful fact that despite being largest producer of sugarcane in the world, we rank among lowest in respect of yield of sugarcane & sugar per unit area as shown in the table. It is not that scope for such an increase does not exist, yields recorded on the mechanised large-scale factory farms in Maharashtra as well as on the lands of certain

progressive farmers compare well with the world records, amply prove that there exists a vast scope in this field. Although, there are many well known obstacles in the way of planned development of sugarcane in the field e. g. small holdings, poor resources, numerous cultivators etc., but these challenges are to be met collectively lest it would not be possible to improve production cost. The urgency & need of the hour calls for greater participation of factory Management in the cane development work which together with the grower and the Government have to make a speedy approach to resolve above problems by following a stepwise cane development scheme based on a rigorous pattern which has to be sincerely adhered to, comprising of following essential elements:

1. Varietal Planning

Soil & Climatic conditions determine the suitability of cane varieties to a particular region. Whole span of crushing season has to be divided into three parts & proper selection of early, mid & late ripening varieties is to be made for growing in order to ensure right and matured variety throughout the season yielding high recovery per cent cane without much fluctuation.

2. Sugarcane Seed

The essence of establishing a healthy crop thereby increasing productivity lies in good quality seed. Experiments have shown that use of healthy seed after proper treatment with hot air/water for making it free from disease, have given higher yields, as revealed by a typical study carried out at the Padegaon research station in following table.

Effect of hot water treatment on yield

Variety		germination		Yield/Hectare (M. Tonne)	
		Treated	Untreated	Treated	Untreated
Co	419	61	65	222	175
Co	740	68	69	240	237
Co	775	63	65	212	170
Co	798	68	77	220	192

However, it would be futile to expect much from the grower in this direction. After obtaining disease free seed from Govt. nursery farm it is to be multiplied in the factory's nursery farm after proper treatment which has to be further multiplied in the secondary nurseries scattered at different places over the entire area of cane cultivation only then proper quality seed could be delivered to the individual grower. If necessity arises, by infestation of some disease, the seed may be changed once in four or five years.

3. Manurial Schedule :

After varietal distribution of whole area is fixed the next step to be carried out simultaneously is fixing manuring schedule for all crops in which the total doses of N. P. K , number of doses, their time schedule of application is to be carried out. For effective implementation it must be ensured by the development staff that sufficient manures & fertilizers are available well in time. The grower should be offered adequate & easy credit facilities to meet the costs otherwise if feasible the grower may be contracted to recover the costs of manures from the cane price. This step is of great importance for achieving uniform crop higher both in quantity & quality.

4. Cultural Operation :—

Timely operation of the cultural treatments is very important for cane development which should be a direct responsibility of the cane Development Department to ensure timely operation within a definite range of expenditure.

5. Irrigation and Drainage :—

Optimum irrigation has to be ensured for better yields because too much irrigation is as damaging to the cane crop as inadequate irrigation. For this, adequate facilities as well as education has to be provided to the grower. Similarly where problem of water logging, due to low-lying areas exists, adequate drainage arrangements have to be made for getting higher yields.

6. Plant Protection

With the expansion of area under sugarcane intensity of pests & disease are finding increased incidence. Pyrilla is making almost annual appearance practically in every region while borers and smut are also on increase. If plant protection measures are delayed it may seriously hamper the growth of the cane despite all other development measures. The cane Development Department should take preventive measures like pre-treatment of setts with mercurial fungicides like Aerton and Auga^llol and planting with only healthy and disease free seeds. It should, however, be ever vigilant and carryout routine inspections throughout the operational area for locating any incidence of pest and take timely action before it takes serious form & spreads to other areas. Use of pesticides like Rogar, Endrive with power sprayers or preferably an arial spray by helicopter would control the pest before it damages the crop.

7. Maturity wise harvesting :—

At last but not the least, one of the most important steps is maturity test before the crop is harvested because even with best develop-

ment measures taken, there is bound to be some difference in the maturity of the crop from plot to plot. Therefore, in order to get best fruits of all development work followed as given above, priorities should be fixed for harvesting according to maturity which would help in maintaining high recovery per cent cane throughout the season.

Besides the important steps outlined above the Development department would be required to assist the growers in providing all necessary infrastructures e.g. tractors, farm implements etc. for scientific cultivation of sugar cane instead of conventional methods using a lot of manual labour which is getting costlier day by day thereby increasing cost of sugar cane production. Similarly, for its own interest, it will have to extend facilities for quick transportation of cane so that it may be brought to the factory as fresh as possible. For instance, Road Development is a state responsibility but the factory should develop the feeder roads linking fields to the factory. All the measures suggested above, if implemented sincerely in a planned & systematic way, are bound to render startling results in the form of higher yields of sugarcane & sugar per unit area. In the starting stage it would require long term planning and co-ordination so much so that it may appear a Herculean task, it would also require sufficient funds, a well organized team of development staff, implements & equipments, transportation facilities etc. but gains which would be achieved would more than offset the investment in raising the standards of cultivation & thereby productivity of the sugarcane. We would be in a position to stand at par with other pro-

gressive sugar producing countries of the world. Even after necessary funds are mobilised & cane development activities are started as per above schedule, prime importance has to be attached to its implementation at full scale with all seriousness without any deviation or slackness on the part of anybody so that fundamental aim of extension of modern scientific cultivation to the grower is achieved which alone has a potential to raise productivity to the desired peaks, otherwise it may mislead to wrong conclusions about the usefulness & feasibility of the whole plan. Unless such an intensified & planned development is carried out, whatever advances may be achieved in the fields of processing technology, a real break through in the economy of sugar production can not be thought of because of the fact that sugar is actually produced in the fields, it is only transformed into crystals in the factory.

While thinking of economising the production even a single gramme of sugar has to be saved. After the cane is harvested, it is in the interest of factory management to see that it is delivered to cane carrier within least possible time because studies have revealed that cane starts deteriorating fast after 24-36 hours of harvest transforming its "Surcorse" content into reducing sugars amounting to an undesirable loss of sugar. Due importance is not given to another important aspect that factory management should exercise rigid control to ensure that only clean cane, free from tops, trashes & leaves is crushed. Studies in a factory have established that processing unclean cane with extraneous matter costs Rs. 97/- per tonne of sugar. This undesirable

extraneous material not only increases the weight of cane for which factory has to pay, it presents problems in course of processing also. Therefore, it has to be avoided even if some extra price for the cane has to be paid.

B. Process Techniques-Modern Approach

Science & Technology constantly progress by under taking researches on specific problem& as a result deliver advanced process techniques and equipment ensuring better productivity with simplicity in operation. Therefore, in Indian sugar industry's economics, importance of improvement in process techniques ranks second only to development of raw material i.e. sugarcane as it directly decides the recovery of finished product from that is available in the raw material & as such has a direct bearing on the production cost. Sugar industry all over the world, has, in the recent past undergone several technological developments in the field of modernisation. Certain notable achievements being (a) application of principle of diffusion in extraction of juice (b) application of thin layer separation principle for separation of molasses from crystals leading to development of continuous centrifugals (c) resistance heating of C-masseccuite, G. P. filters, pans with better boiling characteristics, etc., etc., The basic aims behind all these improvements have been.

(i) Achievement of highest efficiencies in Mill House and boiling House which together ascertain overall performance of the plant.

(ii) Shift from outmoded batch operation at every stage, wherever possible, to the continuous operation. It has been practically

observed that continuous operation has a definite edge over the batch operation owing to its special features viz —

—simplicity of operation with less maintenance & operational cost.

—consistency & uniformity in operation & hence in the production.

—Lower man power and space requirements etc. It is due to this superiority that continuous operation is replacing batch operation stage by stage with the adoption of continuous sulphitor, clarifier, filters, evaporator, continuous centrifugals in low grade masseccuites & within a very near future it may be possible to introduce continuous pans & continuous crystallizers also.

(iii) Efficient Generation & use of fuel and Power by employing high pressure boilers with modern furnaces & heat recovery units with vapour bleeding arrangements.

Modernisation of sugar units incorporating these advances is of greatest urgency for reducing production cost. Indian sugar machinery manufacturers, though not very old in the field, have not lagged behind in development of latest machinery matching with modern technological advances. Indian sugar industry, however, presents a mixed picture. We have both modern, as well as old & obsolete units, mostly steam driven with low pressure boilers, manual feeding of cane carrier, outmoded batch type sulphitors, settling tanks, filter presses, low capacity

vacuum pans with poor boiling characteristics, small sized belt or water driven centrifugals. The result is that such units are worked with heavy cost of repairs & maintenance, give very high manufacturing losses, poor technical performance, heavy time loss due to frequent break downs, high consumption of extra fuel & yet are excessively labour intensive. All these factors lead to an extremely high production cost making these units totally uneconomic which impair the economics of the industry as a whole. Unless these units are modernised to give better efficiencies, any attempt to reduce production cost will hardly succeed because modernisation will not only minimise their losses on various heads, it will also help in reducing excessive labour force having a great impact on the production cost.

Clarification Processes

Barring one sugar factory which employs Middle Juice Carbonation Process, all sugar factories in India are adopting one of the two conventional processes of clarification viz. Double Sulphitation or Double Carbonation and Double Sulphitation. Though these processes are simple and have been improved by continued researches, the severe corrosion to the equipment by sulphur di-oxide is becoming too costly in the context of high prices. This calls for adoption of a new clarification process cheaper but competent of giving better quality of sugar having less corrosive action on the equipment. It is in this context that a new process reported by Dr. Paul already being used in East & South African countries, deserves attention. In this process called

“Defeco Syrup-Lime Phosphitization Process”, up to syrup stage simple defecation process is followed & thereafter defecated syrup is clarified by lime phosphitization, areation & the treated syrup is filtered and used for Boiling strikes. This process being a hybrid process of defeco Melt-lime phosphitization process & Defeco Melt Syrup Sulphitation process, envisages no melting or extra load on the boiling curing stations as in the two processes. Further it has advantages of less consumption of chemicals, complete elimination of sulphur giving corrosive action in the conventional processes, lower sugar loss & better quality of sugar. This process deserves fair trial in respect of feasibility of its commercial adoption. Another process which is under study & trial for its feasibility is DEMINERALIZATION OF CANE JUICE “OR ION EXCHANGE PROCESS” Studies on this process were started by N. S. I. long back but were slowed down due to certain reasons. Now with the active interest & vigorous efforts of Dr. Ramaiah, Director, N. S. I., this process is again under active study and plant scale trials. If it becomes feasible to adopt this process commercially, it would be a big leap forward in achieving better economics of sugar production as processing losses would be drastically reduced with its implementation.

Fuel Economy

New Sugar Factories which are coming up as well as big & modern factories which have incorporated modern devices of fuel & steam economy devices are fairly well balanced in respect of steam generation efficiency & its economic utilization. However, in many existing sugar factories, expenditure on account of

extra fuel burnt in the form of firewood, coal or furnace oil is mounting and comes in lakhs of Rupees. With the present advances, there can be no justification of such a colossal waste having adverse bearing on the cost structure of the industry as also consuming nations natural resources in the present days of energy crisis. Use of extra fuel can easily be avoided if the problem is properly handled. Fuel economy directly depends upon (a) Milling efficiency which determines the quality of bagasse in respect of its moisture content which is inversely proportional to its calorific value. In Indian factories, moisture content varies between 45-52 per cent, the difference between the two in terms calorific value of bagasse being 700 BTU/lb or in other words about 0.2 lb of steam per lb. of bagasse. Therefore, an effective steam economy would require maximum Milling Efficiency which can be achieved by adding adequate number of Mills, using better cane preparatory devices e. g. double set of heavy duty knives, reversal of knives, shredder, a 18-roller tandem with a Donnelly chute, properly loaded with Edward's

accumulator, replacement of kush elevator by DSM screens, = Uniform and regular feed to properly set mills with optimum imbibition will not only yield maximum Milling Efficiency but would also render bagasse with low moisture & low pol per cent giving bagasse of high calorific value. Efficient generation of steam involves efficient burning of bagasse in well designed modern furnaces e. g. Horse-shoe or Spreader stoker with heat recovery units such as air pre-heaters & economizers. Using the generated steam efficiently would require proper working of prime movers & full utilization of resultant exhaust steam by vapour cell, evaporators, juice heaters in a balanced manner without any blow off. The concept of predrying of bagasse by heating before being fed to the boilers will greatly increase the working efficiency of boilers. Continuous & efficient working of a well maintained plant automatically results into fuel economy thereby requiring no extra fuel, saving a major head of the variable costs of the industry.

Variation of Calorific Value of Bagasse with Moisture Present

Moisture Percent Bagasse	55	50	49	48	47	46	45
GCV BTU/lb	3726	4140	4201	4268	4351	4433	4554
NCV BTU/lb	2849	3258	3361	3424	3514	3604	3722

Preventive Maintenance

Preventive maintenance assumes prime importance when we think of economic & efficient working of any industry. It is a dismal fact that in Indian Sugar Industry, due importance has not been attached to it & no advance thinking is developed to balance technical considerations of operations & the maintenance, the result is early deterioration of the machinery making them inefficient & obsolete. The objectives of preventive maintenance are (a) To provide freedom from break downs during manufacturing operations (b) To maintain equipments in their satisfactory conditions of safe operation (c) To maintain equipments at their maximum operative efficiency (d) To reduce to a minimum downtime resulting from break down and (e) To reduce the cost of this maintenance to a minimum consistent with the above objectives. With spiralling rise in costs in all spheres, the financial cost of losses due to unexpected stoppages has also increased in proportion. It is, therefore, of urgent necessity to strictly enforce Preventive Maintenance in all sugar factories in India. The break-downs of machinery can not always be forecasted or avoided but any break down must always be investigated & recorded. Preparation of historical records of all units of plant will be of special use in drawing the conclusions at how such break downs can be avoided in future by taking timely preventive measure. Proper & regular lubrication & correct alignment of moving parts is to be ensured, all standby units should be regularly checked, repaired & kept in condition ready to start. Periodical shut downs have to be planned meticulously for attending all essential aspects of preventive

maintenance. Absolute cleanliness has to be maintained and all sanitary measures taken for avoiding any bacteriological loss of sugar. This would require a well organised Preventive Maintenance team for which excess labour force can be utilised by providing them adequate on-the-job training. This would definitely yield beneficial result in economising sugar production.

Reduction in store consumption & Inventory control

With all above measures of modernisation of process & equipment, preventive maintenance, fuel economy, the consumption of stores is bound to come down. Further the scarcity of resources and economics of production calls for an urgent need of introduction of inventory control using modern techniques of material management like ABC analysis. In many sugar factories, required attention has not been paid to this important aspect resulting into unprecedented rise in the inventory due to impulsive purchases & poor control to such an extent that it becomes a liability rather than asset and money is blocked unnecessarily. In a sugar factory major items of store include Gunny bags, Fuel oil, Firewood, Lime Stone, Sulphur, Lubricants, Machinery spares & Chemicals. Applying system of ABC analysis these can be grouped according to their cost & consumption levels as follows.

Group A Gunny bags, Fuel Oil, Firewood.

Group B - Lime Stone, Sulphur, Machinery, Spares.

Group C - Lubricants & Chemicals.

These should be put under the control of top Management, Departmental Heads & Stores Officer respectively. Their position has to be reported at fixed periods enabling evaluation of safety stocks & Reorder point. Strict adherence to such a scientific control will avoid haphazard purchases, unwanted stock denvolving unnecessary funds lying dead and so would definitely help in curtailing production cost of sugar.

Expansion of Smaller Factories

Capacity of any industrial unit has an important bearing on determining the cost of its finished product. This is especially true in case of sugar factories, the economics of any unit is decided by its daily cane crushing capacity. Gundu Rao Committee, 10 years back recommended 1500 tonnes daily cane crushing capacity to be economic size and even this capacity stands today as marginally economic, that too, under favourable working conditions. As has been described in the earlier paragraphs, in India, a number of factories having an average capacity of 1000 TCD or even less with old and dilapidated equipment are still operating, most of them have grown 'sick' so are running under Government control rendering huge loss to Government exchequer every year by way of their low productivity and high production cost. Any development measure will hardly be successful unless their expansion is carried out alongwith modernisation. The biggest handicap that comes in the way is the cane potential which may not meet the requirements of expanded capacity, as these factories are situated very close to each other especially in East U. P. and Bihar, the present problem spot of the sugar industry.

The only solution lies in replacing three or four such units with a big factory of 3000—4000 TCD capacity in the centre of that area with ancillary industries utilizing its bye products as raw material. Such an step would not only improve the economics of sugar industry but would also accelerate the spread effect of industrialisation in rural India. Unless these "Bleeding Ulcers" of Indian sugar industry are cured, disparities would exist and with limited scope in reduction in the fixed and variable costs under existing conditions, an alround revolutionary curtailment in the cost, sugar production would not be achieved. Now-a-days a number of factories are coming up in the areas where sufficient cane required by them is not available with the results of their uneconomic working for many years, taxing Government exchequer. It would be prudent to give top most priority in planning for stablising and achieving full production potential in these old and ailing units by expanding and modernising them to big and economic units before installing new units. In this context we may follow the example of other leading sugar producing countries like Brazil, Australia and Indonesia where old and small plants, many in number have been replaced by a few big units. But while planning any expansion programme, the mistakes of past should not be repeated and due scope should be left for any future expansion as the capacity which is economical today may not remain economical after a few years. Many and diversified problems would come in the way but these have to be solved jointly by the industry and the Government because economising sugar production with better utilization of natural resources is not the

problem of industry alone, it is on the whole a national problem and any development economising sugar production will set a very healthy trend in the national economy. Sugar industry contributes a substantial amount to the national exchequer by way of various duties and taxes and the Government exercises indirect control on almost every sphere of this industry's activities and hence it is committed to come to its rescue by planning and ensuring execution of healthy its development.

Conclusions

Various factors which directly influence the cost of production of sugar in India have been discussed in brief and suggestions have been made for improvement ultimately yielding better cost structure. Due emphasis has been given to the intensified development of sugar cane which can be exploited as inherent potential of improving productivity. By implementation of other measures like modernisation, Preventive Maintenance, Inventory Control, Expansion of Capacity etc. Efficiencies will be improved, unproductive labour

cost will be reduced, consumptions will decrease and the basic aim of producing cheaper sugar would be achieved. No attempt has been made of working out a rigorous economics of the suggestions made in the article as conditions differ widely from factory to factory. In different regions and the degree to which production cost is reduced will directly depend upon the extent to which suggested measures are implemented. Some progressive factories have already put some of these suggestions in practice and they are reaping the benefits of higher productivity and lower production cost and hence better profitability.

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Table -- 1

Country	Cane yield per hectare Metric tonnes	Recovery	Sugar per hectare Metric Tonnes
Hawaii	198.6	11.4	23.64
U. A. R.	96.8	10.9	10.55
Australia	61.5	14.7	9.06
U. S. A.	61.5	9.4	5.78
Phillipines	59.8	11.4	6.82
Fiji	44.7	13.1	5.88
Cuba	47.0	12.3	5.78
India	49.9	9.9	4.94

Statewise Yield of Sugar Cane in India
(Tonnes per Acre)

State	1971-72	1972-73	1973-74	1974-75	1975-76
Andhra Pradesh	36.0	30.0	30.7	23.9	28.1
Assam	15.2	15.4	16.4	15.5	15.0
Bihar	12.7	14.3	15.0	16.0	14.9
Gujarat	20.5	19.2	20.3	19.8	22.3
Haryana	18.2	17.9	16.0	14.8	17.5
Karnataka	33.2	32.8	31.6	28.1	30.6
Kerala	20.6	21.1	21.9	22.9	21.8
Madhya Pradesh	11.2	10.7	10.8	10.0	12.5
Maharashtra	25.5	26.7	31.8	37.5	35.8
Orissa	25.2	26.4	23.8	25.3	26.3
Punjab	15.9	18.5	21.3	20.2	21.7
Rajasthan	17.7	16.1	19.6	17.1	15.7
Tamil Nadu	33.4	34.1	39.8	36.8	38.6
Uttar Pradesh	15.7	17.6	16.7	16.7	16.2
West Bengal	19.7	20.5	21.4	23.5	23.7

REDUCTION OF WATER REQUIREMENT IN A CANE SUGAR FACTORY — A CASE STUDY

By

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Somaiya Sugar Works Sameerwadi
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ABSTRACT

The water consumption could be reduced from the conventional requirement of 220 m³/hr to as low as 40 m³/hr. by adopting the techniques of judicious reclamation and re-use of cooling water and condensates. As a result, there has been a drastic reduction in the quantity of effluents to be disposed of. Even these are used for sugarcane irrigation.

The Somaiya Sugar Works, Sameerwadi is located in Bijapur District, a notorious drought prone area of Southern India. Very special attention to the questions of water use and water conservation was paid by the Research & Development Division of the Factory from the beginning. The installed capacity of the plant is 2500 TCD. Conventionally, a plant of this size would consume about 220 m³ of water per hour and would discharge anything from 100 m³ to 120 m³/hr as effluent. It was realised early not only that the availa-

ble water resources would have to stretched to the limit to provide this quantity of water but also that the disposal of effluents would present a serious problem.

It was, therefore, decided to make effective use of the water contained in the sugarcane to the maximum extent possible.

To start with, an inventory of the water requirement of the plant was made and classified under various categories. The details are given in Table-1.

Table - 1

S. No.	Equipment	Purpose	Basis for Estimation	Total Requirement in m ³ /hr.
(1)	(2)	(3)	(4)	(5)
A. Cooling Water Requirement				
1. Mill Drive :				
	4 No. Standard Horizontal steam turbines of two pedestal bearings split casing impulse type provided with forced lubrication capable of developing 500 BHP.	Mill Turbines & reduction gear oil cooling.	6.8 m ³ /hr. for each turbine (as per maker's manual)	28.00
2. Mill Bearings :				
	Mill size 850 mm × 1675 mm journal dia. 425 mm total hydraulic pressure 270 tonnes.	Cooling of mill bearing	4.5 m ³ /hr. for each mill (as calculated)	18.00
3. Power House Turbines :				
	1 No. Horizontal multi/stage impulse steam turbine capable of developing 1500 KW with an alternator.	Turbine and reduction gear cooling.	18 m ³ /hr (as per maker's manual)	18.00

Contd.

S. No.	Equipment	Purpose	Basis for Estimation	Total Requirement in m ³ /hr.
4.	Diesel Generating Set :			
	One Skoda diesel engine generating set capable of developing 800 HP	Cooling	(As per maker's manual)	0.35
5.	Sulphitation Station :			
i)	4 No. Sulphur furnace of continuous type.	a) Water cooling jacket.	2.0 m ³ gallons per jacket (estimated) 0.35m ³ /hr. (estimated)	4.00
		b) Scrubber for cooling	0.35 m ³ /hr (estimated)	0.70
ii)	Two electrically driven water cooled air compressors of 500 m ³ /hr. and 250 m ³ /hr. respectively.	—	(as per maker's manual)	3.5
6.	Vacuum filter :			
	One Oliver Campbell type of 8' × 16'	a) For condensor	(as per maker's manual)	10.80
		b) For vacuum pump bearing		
		c) For grand cooling of light and heavy filtrate pumps		

Contd.

S. No.	Equipment	Purpose	Basis for Estimation	Total Requirement in m ³ /hr.
7. Crystallizer :				
	7 No. water cooled crystallizers of 55 tonnes capacity each.	For cooling of C massecuites.	0.8 m ³ of cold water per tonnes of massecuites (C mas.% cane-13)	10.80
8. Centrifugals :				
	15 No. centrifugals of Robert's design of 450 Kg/charge capacity.	For cooling of brake drum.	(As per maker's manual)	32 20
9.	Hot Liquor pumps	For Gland cooling etc.	Estimated	3.15
TOTAL				129.50

B. Water Used in the Process for Miscellaneous Purposes

1.	Imbibition	23% on cane	Hot 73° C	23.60
2.	Make up water for boiler	5% of total generation	Hot	3.30
3.	Milk of lime	1.2% cane (by volume)	Hot	1.50
4.	Oliver and Eimco Vacuum filters	(As per maker's manual)	Hot	10.80

Contd.

S. No.	Purpose	Basis of Estimation	Quality of water temp. preferred.	Quantity requirement in m ³ /hr.
5.	At pans	5% on cane	Hot	6.50
6.	Make up water for condensating system	3% loss on evaporation & 2% windage loss i. e. 5% of total spray capacity of 9 lakh gph.	Cold	202.50*
7.	Cleaning and washing	Estimated	—	9.00
8.	Water for drinking and other purposes			
a.	For Factory (taking 300 persons/shift)	20 gallons per head	Cold	3.85
b.	For colony (for 5000 persons)	@ 20 gallons per head	—	19.80
c.	for laboratory	by actual measurement.	—	9.00
TOTAL				87.25

* It is made up from cane water through evaporation in the pans and therefore, excluded from the total.

From the above tables the total requirement of water will be as follows :

a) cooling water requirement	129.50 m ³ /hr.
b) water used in the process for miscellaneous purposes.	87.25 m ³ /hr.
TOTAL	216.76 m³ /hr.

From the above data, it will be seen that the total water requirement of the plant works out to 216.75 m³/hr. Of this amount cooling water for mill prime movers and power house turbines are usually recycled in most of the factories in India. Thus a balance of 171.75 m³/hr. is made up from fresh water supplies.

At a crushing rate of 2500 TCD or 104 TCH, the quantity of water bought into the process through cane, amounts lost in various ways and that available for collection and re-use are detailed in table-2.

Table—2 (A)

Material Balance and Surplus Available Water	
Crushing	2500 TCD
Juice	95%
Brix	15%
Bagasse	28%
Imbibition	23%
Cane/hour	104 tonnes.
Raw Juice/hr.	99 m ³ .
Water input through Juice/hr.	85m ³ .

Table-2 (B)

S. No.	Loss of water through	Basis	Total qty. of water lost.
1.	Moisture in Oliver cake	Oliver cake % cane 3.50	2.730 m ³ /ha
2.	Evaporation condensor	As per calculations (Ref. Fig. 2)	5.478 m ³ /hr.
3.	Pan condensor	As per calculations (Ref. Fig. 2)	29.750 m ³ /hr.
4.	Final Molasses	Final Mol % cane 3.5 Moisture % 18	0.655 m ³ /hr.
5.	Sugar	Recovery % cane 12 moisture % sugar 0.05	0.006 m ³ /hr.
6.	Boiler blow down, soot blowing, flash etc.	5% on cane assumed	5.204 m ³ /hr.
7.	Total losses		43.82
8.	Surplus available		41.18

It will be seen from the above table that out of 85 m³/hr. of water entering the process through cane, 43.80 m³/hr. is lost in different ways and 41.20 m³/hr. is available for re-use. In addition, if arrangements could be made for re-cycling of the entire cooling water amounting to 109.2 m³/hr. the net requirement of make up water comes down to 65.78 m³/hr. By exercising control over direct consumption points the actual consumption was further reduced to about 40 m³/hr. and the effluent quantity was brought down to about 15 m³/hr.

Towards reaching these values, the following modifications in design and operation procedures were affected.

1. The evaporation station consists of a vapour cell, a quadruple set with vapour bleeding from 1st and 2nd bodies and a suitably designed juice heater in the last body vapour line. The entire boiler feed water requirement is met by the condensates from the vapour cell, 1st and 2nd bodies of the quadruple. This has also helped to solve the problem of scaling in the boiler. The rest

of the condensates go to an over head tank as shown in the condensates flow chart in figure 1.

The plant lay out permits separate collection and storage of condensates for re-use. The condensate of the lowest temperature is used for imbibition there by effecting some economy in steam consumption.

A centralized hot water tank is installed at the pan floor. Supplies to imbibition, centrifugals, pans etc. are drawn from this tank in order of priority by providing draw-off lines at different levels. To ensure availability of water in the centralized tank at all times an arrangement for import of cold water for make up with an automatic level control is installed.

2. Three numbers of masonry tanks for collection of condensates and for raw water provided as in figure 2 ; tank No. 1 of 2300 m³ capacity for raw water, tank No. 2 of 900 m³ capacity for boiler quality condensates and tank No. 3 of 1350 m³ capacity for low temperature condensates.

All cooling water is returned to the system. A study of the inlet and outlet temperature of cooling water at various stations after the introduction of recycling showed that the rise in temperature was not more than 3°C. This has not affected mill bearing cooling to any noticeable extent. All cold water service lines for process consumption were dismantled.

3. The demand for make up water is maximum in the spray system supplying injection water to vacuum pans and evaporators. The spray system consists of an RCC storage tank

of 5400 m³ capacity and the cooling is done partly by spray and partly by criss-cross channelling in the pond. The inlet temperature of injection water is in the range of 30°C to 38°C. Water for the condensor of the vacuum filter is drawn from the evaporator and vacuum pan condensor channel system and returned to the same system.

4. A closed circuit with thermostatic temperature control for reheating and recirculating the water used for heating low grade massecuite was introduced. A similar system was added for recirculating water used for re-heating low grades in centrifugal pug-mills.

5. The requirement of water for testing the plant before starting up, is sizable. The water used for testing vessels like the Dorr clarifier, sulphitation vessel, evaporators and vacuum pans etc. for leaks and for water testing is re-used for the hydraulic testing of the evaporators and vacuum pans etc.

6. Water required for drinking, for use in the laboratory, for washing etc. works out to be about 18 m³ to 23 m³/hr. Utmost economy in the use of water for these purposes is exercised and leaky faucets, glands flanges etc. are attended to promptly. The consumption for these purposes has now been reduced to 10 m³/hr.

7. Washing the floor has been reduced to a minimum. The floors are cleaned once daily-sprinkling with water and then with dry bagasse and sweeping.

8. All juice, molasses and magma pumps have been isolated by providing dwarf walls

around them so as to contain leaks if any and to facilitate mopping up with dry bagasse or washing with the minimum of water.

With the implementation of the above modifications, the total water consumption of the plant was reduced to 40 m³/hr. This being a closed recycling system, periodic analysis of raw water and necessary treatments thereof are made to check the growth of micro organisms etc.

There has been a drastic reduction in the quantity of effluent to be disposed off. Effluents from different stations in the plant were collected separately and a small experiment was conducted to see if these could be used for irrigating sugar cane. It was found that

plants irrigated with mill-house effluents died within a fortnight while those irrigated with effluents from other stations made satisfactory growth.

Alterations were, therefore, made in the drainage system to collect and drain off effluents from the mill house separately. Effluents from other station are passed through a suitably designed oil and grease trap and then are being used for irrigating sugar cane.

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USE OF CONTINUOUS CENTRIFUGAL MACHINE FOR CURING LOW GRADE MASSECUITES

By

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Introduction

The use of Continuous Centrifugal Machines for the spinning of low grade massecuites in India, though has been with a slower pace, is now being increasingly favoured due to their advantages over the conventional batch type machines viz. better and consistent quality of sugar, lower recirculation of molasses, uniform loading on the power system, low power consumption per ton of massecuite handled, economy in labour, low maintenance cost and mechanical simplicity. Besides the above advantages, these machines can cure even the bad massecuites and have greater flexibility in capacity. However these machines have not yet proved to be successful in the curing of A-massecuites mainly because of the breakage of the crystals.

It is a wellknown fact that any increase in the loss of sugar in final mollasses would directly affect the working and the economy of the factory. Due to the general apprehension of rise in final molasses purity in conti-

nuous machines in the mind of many Sugar Technologists, use of continuous machines had been restricted mostly for B-fore curing and C-after curing.

However with modifications in techniques, use of continuous machines for curing of final massecuites is becoming quite popular.

The use of high speed continuous machine over the conventional batch type machine is emphasised due to the following factors :—

1. In Batch type machine, we cannot have higher gravity factors.
2. Batch type machine works on a packed bed filtration theory and hence demands for a porous wall. These two factors limit the application of a batch type machine for the curing of a massecuite having small size crystal higher brix and high viscosity which are considered necessary for achieving the optimum exhaustibility. But since a continuous high speed machine works on a thin layer theory where in the

thickness of massecuite layer is probably one to two crystal deep only, good separation of even viscous molasses, in short time, is achieved.

3. Many of the Technologists abroad and in India have observed a lower final molasses purity with the use of continuous machine by suitably modifying the boiling techniques and proper conditioning of massecuite before curing.
4. Recirculation is minimised with continuous centrifugals.

Types of Continuous Centrifugals :

There are many machinery manufacturers making continuous centrifugals claiming advantages over the others. But basically two types of continuous centrifugals are now prevalent in the market. These are :

(i) *Vertical Centrifugals :*

These are machines having baskets rotating on vertical axis. This type is very common and is more in use in India and abroad.

(ii) *Horizontal Centrifugals :*

These are Continuous machines rotating on horizontal axis.

The main design features of some of the common makes are given in annexure No. 1.

At Daurala we have the experience of working with both these types of Centrifugals. Horizontal machines are of Buckau Wolf make C-1100 Continuous centrifugals working as C-aiterworker and B-foreworker. Vertical

type Walkonti 8/34° are working as C-foreworker. In this write-up we have given working of these machines particularly with regard to curing of final massecuites.

Studies at Daurala :

At Daurala 2 nos. Walkonti (8/34°) Centrifugals were installed as C-foreworkers in the season 1973-74. Centrifugal battery for handling C massecuite comprised of two nos. Walkonti and 3 nos. B. M. A (641 mm × 1143 mm size) Batch type machines. Full season trials with this arrangement were carried out in successive seasons 1973-74 to 1975-76 and the performance of the Continuous machines was found so encouraging that we replaced all the three Batch type machines with 3 nos. Walkonti machines during off-season'76. Now the C-foreworker battery at Daurala consists of 5 nos. Walkonti Continuous centrifugals only. The comparative working results for the season 1970-71 to 1977-78 (upto 15.3.78) is given as table No. 1.

It can be inferred from the table No. 1 that even when processing the inferior juices which result into higher production of molasses, the loss in final molasses can be controlled by reducing the purity of final molasses. Details of the various studies made at Daurala have already been published in the Proceeding of STA, 1974 and 1975. Therefore, only a few observations which need special mention have been given in this paper. Since the authors do not have any experience of working with Contrifugals other than Walkonti as C-foreworker, only the performance of this model has been discussed.

Table-1

Sl. No.	Particulars	Only Batch type machine			With 3 Batch type and 2 Continuous machine			With Continuous machine only.	
		1970-71	71-72	72-73	73-74	74-75	75-76	76-77	77-78 (upto 15th March'78)
1.	Mixed juice Pty.	78.04	79.64	80.98	78.21	81.12	80.24	79.77	79.83
2.	N. S in Mixed juice % cane	3.31	3.03	2.84	3.22	2.85	2.94	3.07	3.07
3.	C-Massecuite :								
	— Brix %	99.30	99.34	99.65	99.57	101.47	101.03	101.04	100.89
	— Purity	63.09	62.16	62.68	60.75	59.92	59.99	59.02	58.80
4.	Final Molasses :								
	— Brix %	96.37	96.24	97.04	94.91	99.19	98.91	97.98	98.05
	— Purity	36.25	36.02	37.59	35.89	36.20	35.97	36.07	35.86
	— % cane	3.99	3.54	3.52	4.24	3.21	3.52	3.69	3.59
5.	Pol loss in final molasses % cane	1.39	1.23	1.29	1.44	1.15	1.25	1.30	1.26

Capacity of Walkonti 8/34° Machine :

Capacity of these machines is largely governed by the viscosity and fluidity of the molasses film surrounding the crystal, crystal content and their size distribution, purity of the massecuite and the purity of cured sugar to be obtained, open screen area and the amount of wash water applied etc.

(i) Capacity at different brixes :

It was revealed from the experiments that while keeping the other parameters in the limited range, the capacity of Walkonti machine can be increased by 60% or more by reducing the brix of the massecuite. However reducing the brix below 98 by dilution was found to have an adverse effect on the purity of final molasses.

(ii) Capacity at different purities :

Capacity of Walkonti reduces at lower purity (55-56 units) of the massecuites and can be increased by 50-60% by increasing the purity (60-61) of the massecuite. However, it is observed that the capacity at lower purity can also be increased by reheating the massecuite to saturation temperature in the pugmill or in the feeding chute quickly without any increased loss of sugar in final molasses. Capacity of Konti machine which was found to be 1.5 — 2.0 tons/hour depending upon viscosity, crystal content brix, and purity of the massecuite etc. increases to 2.5 — 3.0 tons/hour after reheating the massecuite to saturation temperature.

(iii) Effect of wash water application on capacity :

Capacity of Walkonti can be increased considerably by applying wash water as discussed elsewhere in this note.

2. Crystal Damage :

Some amount of crystal damage in the continuous machine is inevitable. This is mainly due to the fact that the crystals are subjected to high frictional forces on screen and further to violent impact when discharged at high peripheral speeds into the monitor casing. We did not come across any problem in curing C-magma obtained from Walkonti machine in a continuous C-after worker centrifugal machine (Buckauwolf C-1100). However M/s. T. T. Oommen & Menon found it impossible to cure this magma in a Batch type machine. This problem propose to study this phenomenon at Daurala after making necessary arrangements during the current season itself. Damage to sugar crystal is not of much importance where it is to be melted. The effect of crystal damage may be more when this sugar is to be used as a seed magma. However in this connection it has been argued (B. D. Sockwill, Proc. ISSCT-1964) that the very final grains get dissolved either in magma mixer or during pan washings. The remaining damaged fine crystals heal up fast during the course of crystallisation in the pans and towards the end of the strike perfectly shaped sugar crystals result from the irregular seed magma obtained from Continuous Machine is being used without any difficulty in some of the sugar factories at Zahirabad and Vuyyuru etc.

3. Final Molasses Purity :

Earlier experiments conducted at Daurala (Ref- N. N. Joshi G. C. Singh, R. C. Singhal, STA, Proc. 1974) showed that if the same material is cured in the Batch and Continuous type Centrifugat the purity of final molasses obtained from Continuous machine is normally higher by 1-1.5 units when compared to Batch type machine. However there were cases when the purity of molasses obtained from Continuous Machine was found to be on lower side after modifying the process. In view of this the following steps were taken to exploit the optimum use of high speed Continuous Machines.

- (a) Massecuite purity were reduced from 70-62 to 57-59 units.
- (b) Crystal size was reduced from—.3-.35 mm to .2-.25 mm.
- (c) Efforts were made to have max. crystal content and high brix of the massecuite possible within practical limits.
- (d) Properly cooled massecuite in the crystallisers were heated in pugmill before its curing to saturation temperature as determined with the help of saturoscope from time to time.

By adopting the above measures it was found that the purity of final molasses obtained from continuous machine was lower by 0.5 — 0.8 units when compared to Batch type machines.

4. Increrse in the purity of C-Single cured sugar :

Purlty of C-single cured sugar obtai-

ned from Walkonti machines was higher by 3-6 units. This resulted in improved sugar quality, reduced circulation of non-sugar, lesser production of C-massecuite thus increasing the capacisy of the battery to handle more crush and bettor exhaustibility of final molasses due to reduced viscosities.

5. Effect of wash water application :

It is an acknowledged fact that the mola-sses film nearest to the crystal surface is most exhausted one. It was thought that since the time of contact of wash water fluid film of molasses surrounding the crystal travelling on the screen, would be only a fraction of a second, the application of wash water within certain limits may help in diluting the film of molasses adhered to the crystal without dissolving any sugar. Hence it would be possible to increase the through put of the machine for achieving the same quality of cured sugar.

Two arrangements of using wash water have been provided with the original equipment.

- (a) The water added in the feed chute i.e. coaxial application of wash water.
- (b) The water applied in a direction normal to the screen ie. Radial washing arrangement.

The axial wash water acts mainly as a lubricant between the feed and the surface of the screen and has a little effect on the mola-sses film adhering to the crystal. At times it was also seen that the massecuite used to fly off the screen due to the absence of a suitable mixing device hence trials were conducted only with the radial washing arrangement.

One nozzle of 1.2 mm orifice dia. for spraying wash water at 2 kg/cm^2 pressure covering a height of 90-100 mm from the accelerating cup, the nozzle being about at 50 mm distance from the screen, has been fitted. The wash water used had been measured through a rotameter. The following inferences were drawn in this regard :

- (a) There was no significant increase either in the capacity of the machine or in the purity of final molasses from Konti machine at a wash water consumption of 1.5-2.0% of the massecuite.
- (b) Capacity gain of 80-90% was observed by increasing the water consumption to 3.0 — 3.5% of the massecuite. However the purity of final molasses still remained unaffected possibly because the net dilution per cent molasses remained the same due to increased throughput.

6. Use of resistance heater :

Use of resistance heater may be exploited for quick re-heating of low grade massecuite in shortest possible time just before curing. We propose to conduct trials with a resistance

heater designed by N. S. I. in our Walkonti machines. It may be mentioned here that the resistance heater cannot be used successfully with Batch type machines since it would result in local overheating of massecuite due to Batch type operation.

7. Life of Screen :

The main problem with Continuous Centrifugals is the life of screen which in case of C-fore curing is in the range of 45-60 days only when imported screens are used. The indigenous screens give much lower life and are not uniform.

Conclusion :

A Continuous Centrifugal in the sugar industry has proved to be an indispensable equipment. The earlier conviction that Continuous Centrifugal result in higher Purity of final molasses, has been ruled out by suitable modifications in the boiling and conditioning of the final massecuites. Reduced recirculation of molasses due to better quality sugar obtained helps in increasing the effective capacity of the boiling house equipments and minimising the fluctuations in the quality of bagging sugar.

Annexure No. 1

Design Features of few Continuous Centrifugals.

Sl. No.	Particulars	Walchandnagar Walkont 8/34 th C-foreworker.	Buckau Wolf		K. C. P.	
			C-1109	SC-1100	FC-1000 (8/30)	FC-1000 (8/34 ^o)
1. Basket :						
a)	Type of basket	Vertical	Horizontal	Vertical	Vertical	Vertical
b)	Material of construction	Stainless steel	Heavy duty casted steel.	Stainless steel	—	—
c)	R. P. M.	220	1640	1500	1900	1900
d)	Dia. at the top	750 mm	1100 mm	1057 mm	915 mm	1000 mm
e)	Max. gravity factor	2020	1560	1285	1845	2020
f)	Peripheral speed	89.2 ml/sec	94.3 mt/sec	—	—	—
g)	Semicone angle	34/30 ^o	34 ^o	34/34 ^o	30 ^o	34 ^o
2. Centrifulan Line :						
a)	Size of perforations	.06 × 1.66 mm	.09 × 1.68 mm	.09 × 1.68 mm	.09 × 1.68 mm	.06 × 1.66 mm

Contd.

Sl. No.	Particulars	Walchandnagar Walkont 8/34 ^o C-foreworker	Buckau Wolf	K. C. P.	
		C-1100	SC-1100	FC-1000(8/30)	FC-1000 (8/34) ^o
b)	Material of construction	Hard chrome plated nickel	Nickel with chromium plating.	Nickel with chromium plating.	Nickel with chromium plating.
c)	Life	35-45 days Indeginous.	45-60 days	One season at C-afterworker.	—
3. Motor :					
a)	Type	Quirrel cage	—	—	—
b)	H. P.	50	50	50 TEFC	60
c)	R. P. M.	1440	—	—	1440
4.	Running load	30-40 amp.	50-60 amp.	55-90 amp.	—
5.	Lubrication	Oils is circulated.	Oil bath	No lubrication is required.	Only greasing is required.
6.	Feeding device	Open	Closed	Closed	Closed.
7.	Arrangement for separation of heavy and light portion of molasses.	Not provided	Provided	—	Not provided.
8.	Drainage of molasses.	No problem	No problem	No problem	No problem

Contd.

Sl. No.	Particulars	Walchandnagar Walkonti 8/300 C-Foreworker			Buckau Walf		K. C. P.	
		C-1100			SG-1100		FC-1000 (8/30) FC-1000 (8/340)	
9.	Discharge of sugar.	Free discharge of sugar & no problem of clogging.	Free discharge of sugar & no problem of clogging.	Free discharge of sugar & no problem of clogging.	Free discharge of sugar & no problem of clogging.	Free discharge of sugar & no problem of clogging.	Free discharge of sugar & no problem of clogging.	Free discharge of sugar & no problem of clogging.
10.	Feed control.	Manual	Manual	Manual	—	Manual	Manual	Manual
11.	Safety devices for checking foreign matter coming with feed.	Arrangement made in pugmill and feeding chute.	Strainer has been provided in distributor cone.	—	—	Arrangement to be provided in pugmill.	Arrangement to be provided in pugmill.	Arrangement to be provided in pugmill.
12. Space Requirement :								
a)	Area of base required on platform.	2.5 × 1.75 mt	3.5 × 2.0 mt	—	—	—	—	—
b)	Height of pugmill from working platform.	2.25 mt	3.8 mt	—	—	—	—	—

FACTORS AFFECTING TOTAL POLYPHENOLIC CONTENT IN CANE JUICES AND THEIR FATE DURING CLARIFICATION

By

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ABSTRACT

In an effort to study factors that influence high phenolic production in cane and cane juices, large number of analyses for total polyphenolic contents (TPP) have been carried out. It has been observed that variety in question, tissue source, disease and staling of cane considerably contribute to total polyphenolic content in cane juices. Significant changes within the same variety appear to be due to environmental factors that stimulate synthesis of phenolic derivatives in the rind tissues of cane. To assess means of their elimination, the raw juices were clarified by carbonation, defecation and phosphotation process. Estimation of T. P. P. content before and after clarification indicated carbonation to be superior to later two processes.

Three types of organic non-sugars viz. melanoidins, caramels and phenols are known to be responsible for colour formation in cane juices (10) of these, former two group of compounds are formed during processing while cane pilant is the source for the later ones. Phenolic compounds, also referred to as polyphenols, consists of basic skeleton of benzene ring to which methoxyl, hydroxyl and carboxyl groups are attached and are formed through shickmic acid pathway (8). Wide variety of compounds such as aromatic amino acids, phenolic acids, coumarins, tannins, lignins, flavanoids are considered to

be plant phenolics (17), Geerligs (5) as early as in 1915, pointed out that dark coloured varieties of cane possess significant amounts of anthocyanins. Eventually, number of reports (3, 21, 22) appeared describing the chemical nature of these pigments and other phenolic derivatives in the cortical and epidermal tissues of sugarcane. Relationships have been observed in sugarcane between the phenolic content and disease resistance (18,6) polyphenol oxidase, the enzyme system responsible for catalysing reactions of coloured products in cane and cane juices, has been isolated and characterised. Gross and Coombs (6, 7)

succinantly demonstrated that Enzymatic and non Enzymatic colour formation in cane juice is due to phenolic acids. Convincing evidences are now available to believe that various phenolic compounds are present in cane tissues (1, 23, 24, 18), Juices (4) molasses (9) and even in raw and refined cane sugars (2). While under Indian conditions detailed studies (12, 15) have been taken up with regards to caramels and melanoidins, the work in respect to phenolic compounds appears to have been paid relatively less attention. Apparently, there are two aspects that deserves attention in this regard. Firstly, if cane plant is a source of polyphenols what are the factors that induce phenolic production in cane, thereby inducing more coloured compounds or colour precursors in milled juice of cane. Secondly, it is essential to note their degree of elimination with different schemes of clarification because in recent past Sharma (20) has pointed out the difficulty caused by polyphenols in the settling process (2).

Methods & Materials

Cane stalks of different varieties and divergent set of conditions (details of which mentioned separately) formed basic material. Throughout the work, unless and otherwise mentioned the procedures adopted for the extraction and the estimation of total phenols were uniform. Everytime samples were crushed thrice in a power driven laboratory crusher filtered and Brixes were recorded. The juices were diluted ten times and the total polyphenols were cistimated colouremetrically in accordance with the procedures described by Swain and Hills (22) with suitable modifications. The optical density value of the blue

colour complex formed between "Folins—Denonis" reagent and phenols in an alkaline medium at pH 9 was measured at 720 nm on Beckman spectrophotometer (D. B. Model). Total polyphenolic content was determined by referring to a standard curve of 1, 3, 5. phloroglucinol prepared earlier, within the range of 50–300 ug. Results have been calculated for 100° Brix to eliminate discrepancies of brixes of samples.

Raw juices were clarified by different clarification schemes using standard methods and the TPP contents were evaluated before and after clarification in each case. In phosphotation, 1.0% lime of 10° Be was used and a dilute solution of phosphoric acid was employed to neutralise the lime. The juice was boiled and allowed to settle to get the clarified juice.

Results & Discussions —

(A) *Factors influencing polyphenolic content in cane juice—*

(1) TPP content in cane juices as function of variety—

Considering genetic factor to influence total polyphenolic content in cane juices, sugarcane comprising of early, mid-early and main season varieties have been analysed. Among varieties that were analysed BO. 80, 88, 89, 91, 92, 96 and BO. 99 were planted in February 1977 and were of 12 months old when analyses have been carried out. All the remaining varieties of the present study were planted in October 1976 and attained 17 months age at the time of analyses. Table I shows the results of these analyses.

Table-1

Total polyphenolic content (TPP) in different varieties of sugarcane.*

Early.			TPP expressed as mg/l/100° Brix.			Main Season.		
			Mid - early.					
Variety.	Brix.	TPP.	Variety.	Brix.	TPP.	Variety	Brix.	TPP.
BO.89	17.82	4780	BO.	21.32	5394	BO.17	21.82	4720
BO-99	15.49	4196	BO.3S	19.75	5582	BO.74	20.12	5318
CoP.2.	19.39	4089	BO.70	20.82	5515	BO.84	20.69	5558
			BO.76	20.22	5291	BO.88	1932	5331
Mean.		4355						
			BO.91	18.22	4171	Co.1148	21.02	6789
			CoP.1	21.12	4078	Co.1158	20.55	5182
			BO.92	20.22	6627	Mean.		5478
			BO.96	17.12	7827			
			Mean.		5561			

* Each figure represents mean of three replicates

It can be seen from the above results that TPP content was lowest in CoP. 1 (4078 mg/l/100° bx) and in highest in Bo. 06. (782 mg/l/100 Bx) and in between two ranges there was considerable difference among varieties.

The mean values of TPP contents of early, mid-early and late varieties were 4355 mg/l/100° Bx, 556 mg/l/100° Bx and 5478

mg/l/100° Bx⁴ respectively. This indicates that more quantity of TPP contents was present in mid-early varieties than in early or main season varieties.

All the analyses were carried out during middle of February when the mid-early varieties were in peak of maturity while the early varieties were in decline phase and the main season varieties were in the ripening

phase. Therefore, with the results obtained it would be difficult to conclude whether TPP content in cane plant is a function of genetic character or maturity of cane. This aspect needs further detailed study. Added to this, the results also opens possibility to study whether preponement or extension of maturity phase has any influence on TPP content in a particular cane variety.

By and large BO varieties contained less TPP content when compared to Co. 1148 and Co. 1158. According to Rao et al (18) phenolic

content in cane increase resistance to red-rot and other diseases. High amount of phenols in Co. 1148 and Co. 1158 can be attributed to this as both the varieties are resistant to red-rot.

7. TPP content in cane juice as a function of tissue source.

To ascertain the distribution of total phenols in sugarcane stalks TPP contents have been estimated in different portions of cane by extracting juices from top, middle and bottom portions.

Table 2

TPP content in different parts of sugarcane*
TPP content expressed as mg/100^g Brix

Variety	Top	Middle	Bottom	Mean	Mean difference
Co.1148	8350	5774	5422	6515	1952
BO.34	6208	5726	4545	5493	1509
BO.70	5952	4995	4259	5069	896
Mean	6887	5489	4742		
Mean difference	2265	526	675		

* Each figure represents mean of three replicates

In all the three varieties, tops possessed maximum and bottom portions contained minimum phenolics. The middle ones had quantities in between two. Highest phenols in tops can be attributed to the active growth processes and higher metabolic turnover taking place in these regions (1). Maximum fluctuations among the varieties strikingly pronounced in tops (mean difference 2265 mg/l litre 100° Brix), then in bottom (675 mg/100° Brix) and least in middle portions (626 mg/l/100° Bx). More interesting feature was the degree of variation within the same variety but due to change in portion of cane. For example in Co. 1148 alone amount of total phenols in tops was 2576 mg/l/100° Bx and 2928 mg/l/100° Bx higher than middle and bottom portions respectively. The difference between middle and bottom portions was 332 mg/l. Identical trends were recorded in BO. 34 and BO. 70 varieties. Thus these results emphasize that when cane with more tops is supplied to the mill for crushing there would be greater possibility in increase of TPP in resultant mixed juices.

8. Effect of staling & disease infection on TPP content of cane

In these series of experiments millable

stalks of Co. 1148, BO. 70, BO. 34 were subjected to staling in similar conditions for over 10 days (at average temp. 30°C Min. 14°C and humidity 60) thereafter analyses were carried out for TPP content (Table 3). Staling increased TPP content in every variety in question. Variety BO. 34 was severely affected in comparison to BO. 70 and Co. 1148 per cent increase of TPP content in stale cane over fresh cane was 2.80, 4.62 and 8.07 in Co. 1148, BO. 70, BO. 34 respectively. Additional analyses which involved comparison of healthy and disease infected (Ued Rot) stalks of Co. 1148, BO. 74 and BO. 3 indicated 95.62%, 11.62% and 12.14% increase of TPP content in diseased canes over fresh canes. Phenolic derivatives mainly phenolic acids such as chlorogenic acid, protocatechuric acid etc. are known to be fungi-static substances (19). In certain Co. varieties Rao *et al* (18) found incidence of red rot disease stimulated production of phenols. Present results corroborates these observations, for the three varieties, in Co. 1148 red rot infection was prevalent in stalks accompanied by maximum TPP content in resultant juices. The data, therefore, clearly suggests the probability of more polyphenols in milled juices when stale and diseased canes are crushed.

Table 3
Staling and Disease Incidence as Factors Effecting TPP
Content in Cane Juices*

Condition of varieties		TPP Content as mg/l/100° Brix	% Increase
Co.1148	Fresh cane	6759	
Co.1148	Stale cane	6948	2.80
BO.70	Fresh cane	4130	
BO.70	Stale cane	4330	4.62
BO.34	Fresh cane	5693	
BO.34	Stale cane	5848	6.02
Co.1148	Healthy cane	6694	
Co.1141	Diseased cane	13095	95.62
BO.74	Healthy cane	6146	
BO.74	Diseased cane	6860	11.62
BO.3	Healthy cane	5710	
BO.3	Diseased cane	6403	12.14

* Each figure represents mean of two replicates.

Influence of environmental factors on TPP content in sugarcane

In order to study influence of agroclimatic conditions on phenolic content, canes from different areas of East U. P. and North Bihar but of similar variety and age (Feb. planted) have been analysed for TPP content and results are presented in table 4.

Table—4
TPP Content in Cane stalks of Different Areas

Area	TPP AS mg/l/100° Brix
BO.70	
Chanpatia (North Bihar)	2708
Barachakia („ „)	3997
Marhowrah („ „)	5019
Kathkuiyan (Eastern U. P.)	4174
Padrauna („ „)	4130
BO.88	
Marhowrah (North Bihar)	5176
Pusa („ „)	4538
BO.89	
Marhowrah (North Bihar)	4812
Pusa Farm („ „)	4316

From Table 4 it is apparent that BO. 70 variety of Marhowrah area contained highest TPP content (5019 mg/100° Bx) and Chanpatia area had the lowest (2703 mg/l/100° Bx). That means there was as much as 86% variation in TPP content of BO. 70 among two paces. This fluctuation can be attributed to either change in the soil, agronomical practices and nutritional aspects or environmental factors. Comparison of variety BO 88, BO 89 grown in

Marhowrah and S. R. I. Pusa were also in agreement with this kind of fluctuations since there was 14% and 11% more TPP content in canes from former area. All the above results varifiesy the earlier observation that environment and soil as well as nutritional conditions (19) exert their influence on phenolic production in plants.

To further elucidate influence of environ-

ment two varieties Co. 1148 and BO. 70 were analysed for TPP content in outer peelings of sugarcane (rinds) and free tissues of normal and coloured canes. It may be pointed out that in both BO. 70 and Co. 1148 due to detopping detrashing of partially immature leaves, and due to lodging several millable canes have attained dark red colour. The normal canes of Co. 1148 were yellow

in colour while BO. 70 was yellowish green. Morphological difference was not observed in coloured canes of Co. 1148 and BO. 70. From both the types of cane phenols were extracted in 8% ethanol with 1% HCl and TPP contents were estimated in routine manner. Results of these experiments are summarised in Table 5.

Table - 5

TPP content in normal & coloured canes as mg/g fresh weight Rind

Variety	Rind			Tissue		
	Normal	Coloured	%Difference	Normal	Coloured	%Difference
Co. 1149	2.8	18.60	564.29	1.5	1.65	10
BO. 70	3.2	20.00	525.00	1.08	1.70	6.25
%Difference	14.29	7.00	—	6.67	3.03	—

* Each figure represents mean of three replicates.

From the data it is apparent that good amount of difference in phenolic content among normal canes of varieties Co. 1148 and BO. 70 is there in both rind (14.29%) and rindfree (6.67%) tissues. This corroborates with earlier contention (5) that white and yellow coloured cane possess practically no anthocyanins but in red coloured cane they would be in high amount. In between Co. 1148 and BO. 70 degree of variation in TPP content was more predominant in rind tissues (14.29% and 7.00%) than in rind free tissues (6.67% and 3.03%). The most significant

point of interest is, difference in TPP contents of same variety. In other sense, the rind tissues of coloured Co. 1148 and BO. 70 possess 584.25% and 525% more TPP content in comparison to rinds of normal canes. Likewise rind free tissues exhibited 10% and 6.25% difference among normal and coloured canes.

The data therefore, clearly indicate that, influence of genetic and environmental factors would be pronounced on exogenous phenols rather than on endogenous phenols. The

significant production of anthocyanin in cane rinds of same variety can be attributed to the detopping of leaves, detrashing of partially immature leaves and mature standing cane left in the field in hot months, resulting in exposure of cane rinds to high sunlight insensitivities. Similarly lodging of cane also enables more unit area per acre of cane exposed to the sunlight. It is evident that photo induced anthocyanin production, takes place in higher plants (17). Conceivably canes of this kind after being crushed in the mill renders more polymers of phenolic compounds. These phenolic compounds on hydrolyses yield simple phenols or phenolic acids which impart colour in the cane juices. Results are in agreement with views of several workers who reported (3, 5, 10, 23, 24) that on acid hydrolyses or alkalifusion, anthocyanin and flavone glycosides of outer peeling of sugarcane give simple phenols (phloroglucinol, and catechol) and phenolic acids (protocatechuric, chlorogenic and vanillic acids). Carpenter (2) reported 21 compounds either coloured or precursors of coloured compounds in raw and refined sugars whose source was cane plant. Another factor of importance is, throughout all the analyses (some unpublished data) (Table 5) we have experienced that the cane from Marhowrah

Factory contained higher amounts of total phenols and incidentally this unit suffered from severe colour problem during processing. The above confirms the argument that factors inducing colouring of rinds cumulatively induct more phenols in cane juices.

In light of observations, studies have been extended to extraction of TPP from cane. Table 6 show comparative data about extraction of TPP during crushing of cane. TPP content was 2636 mg l/100° Bx less in laboratory crusher cane juice as compared during milling in the factory. Obviously this was due to cane preparation in the factory in which rind tissues were completely macerated prior to extraction. It may also be observed that even with laboratory mill during first crushing without any water addition the amount of TPP was less (19.2%) as compared to the amount of TPP obtained through second crushing which involved addition of maceration water. The increase of TPP content in secondary juices indicates the possibilities of extraction of larger quantities of phenolic crops of cane plant as a result of application of higher pressures as against the primary juices.

Table—6

Extraction of TPP with laboratory crusher and during milling.*

Type of juice.	TPP as mg/l/100° Bx	% Increase.
Laboratory crusher :		
1st crushing—	3659	—
2nd crushing—	4528	19.20
During milling :		
Primary juice—	5782	—
Mixed juice—	7166	24.00

* Each figure represents mean of three replicates.

Elimination of polyphenolic (TPP) compounds during clarification

The elimination of TPP compounds during clarification was studied by following various clarification schemes. This was done by clarifying raw juices obtained after crushing the cane in hand mill, following three clarification processes viz; defecation, carbonation and phosphotation. The studies on the elimination of TPP during clarification using sulphitation process could not be undertaken due to interference of sulphur dioxide in the

method used for the estimation of TPP. However, studies are still in progress and efforts are being made to modify the method in such a way so as to eliminate completely the interference caused by the presence of sulphur dioxide.

In defecation process, the raw juices were clarified using three different heat-lime sequences. Table 7 shows the results on the elimination of TPP employing various schemes of defecation process.

Table—7

**Influence of different clarification schemes in defecation process
on the removal of total polyphenolic content**

Sl. No.	Type of Juice.	Corr. Bx.	mg/l 100° Bx.	Removal	O. D. of Jc. at 420 nm at pH 7.00
1.	Raw juice	15.87	4411	—	—
2.	C. juice 1.	16.14	3346	24.14	0.76
3.	C. J. 2.	16.32	3064	30.54	3.77
4.	C. J. 3.	16.32	3450	21.28	0.78

C. J. 1 - Raw juice is heated to 70°C. Lime was added to bring the pH to 7.00.

C. J. 2—Lime was added to bring the pH to 7.0. The juice was boiled, and settled.

C. J. 3 - Lime was added to bring the pH to 6.0. The juice as then was heated to 70°C and more lime was added to make the pH 7.0 It was then boiled and settled.

* Results are average of two sets.

It can be observed from the above table that the 2nd scheme gave the maximum elimination (30%) of TPP. The usual defecation process (1st scheme) could eliminate only 24%. Table 8 indicates the elimination of TPP compounds during clarification using various schemes. In case of carbonation process, the TPP content was determined in 1st carbonated, 2nd carbonated and final clarified juice. pH of the final clarified juice was adjusted to 7.00 with triple superphosphate solution and not with sulphur dioxide in order to eliminate the interference due to SO₂.

Table—8

Removal of total polyphenols during various clarification processes*

	Corr Bx.	mg/l/130°Bx.	%removal.	O.D. at 420 nm
I. Defecation :				
[a] Raw juice	15.87	4411	—	—
[b] Clear juice	16.14	3346	24.14	0.76
II. Carbonation :				
[a] Raw juice	16.14	3563	—	—
[b] 1st carbonated juice	13.88	2616	26.57	0.38
[c] 2nd „ „	13.66	2562	28.09	0.26
[d] Final clear juice.	13.49	2278	36.06	0.17
III. Phosphotation :				
[a] Raw juice	16.59	4256	—	—
[b] Clear juice.	16.27	3445	20.01	0.45

s Results are average of 2 sets.

It may be seen from the above table that during first carbonation which was carried out at pH 10.5, 26.57% elimination of total polyphenolic compounds was observed which might be due to the adsorption of molecules of polyphenols on the surface of calcium carbonate (14). Since during 2nd carbonation, the excess of lime is precipitated (11) by passing carbondioxide, the possibility of the adsorption of total polyphenolic compounds on the surface of calcium carbonate should

increase. This is exactly obvious by the results mentioned in the above table where the TPP content of the 2nd carbonated juice is shown to be only 2562 mg/l when evaluated on 100° Bx. A further fall in TPP content was observed by the final clear juice. Thus the elimination of TPP in the carbonation process was found to be around 36%. The phosphotation process could eliminate only 20% TPP which seemed low. It was thus interesting to observe that although the clarified juice

obtained in phosphotation process showed lower optical density value as compared to one obtained during defecation process, the removal of TPP during phosphotation was found low than in defecation. The fact indicated that the removal of TPP content and the removal of colour till clarification stage had possibly no direct correlation. Further greater elimination of TPP during carbonation process as compared to that in phosphotation processes indicated that the adsorption of polyphenolic compounds on the surface of calcium carbonate precipitate was probably more than on the surface of calcium phosphate precipitate. Further investigations to ascertain the possible mechanisms on the elimination of polyphenolic compounds during clarification employing various schemes are still in progress.

Conclusions

The analytical data obtained through various analyses emphasizes that genetic and environmental factors tagged with tissue source and healthy as well as freshness of the cane cumulatively effect TPP content in cane juices. It could be significantly observed that factors

which induce phenolic pigment synthesis in rind tissues of cane tend to increase the polyphenolic content in resulting juice. The work done also indicate that extent of elimination of TPP during clarification depends upon the process of clarification adopted. This is because removal per cent of TPP was 24.14 in defecation, 36.06 in carbonation and 20.01 during phosphotation. Larger per cent elimination in carbonation may be attributed to adsorption of phenols on the surface of calcium carbonate precipitate. Further work with regards to the formation of polyphenols in cane plant with age and under specific conditions of fertilization and manuring in different varieties is in progress. Efforts are also underway to study behaviour of phenols during sulphitation process of clarification of cane juices.

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BOILING HOUSE PERFORMANCE INDICATORS

By

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ABSTRACT

Virtual Purity of Molasses is offered the Identity as "The Effective Boiling House Control"

(ii) Reducing of Recovery is limited to the Mean Reduced Juices Purity and Virtual Boiling House Efficiency, a Performance Indicator is evolved.

As an introduction of the subject and as to offer my regards to Noel Deer, I will try to express the Virtuality of the Virtual Molasses.

lost solids during the process. The Purity of this left over total solids is known as The Purity of Virtual Molasses. It can be calculated as below :—

Virtual Molasses is the product of the total

$$\text{Virtual Purity of Molasses} = \frac{\text{Total Sugar gone in wastes}}{\text{Total Sugar and non Sugar gone in wastes}} \times 100.$$

$$(i) = \frac{100 - r}{100 - r + \frac{(10000 - 100)}{J}} \times 100$$

$$(ii) = \frac{J(100 - r)}{J(100 - r) + (10000 - 100J)} \times 100$$

$$\text{OR} \quad \frac{J(100 - r)}{10000 - RJ} \times 100$$

In the above equations r , the Boiling House Recovery is first arrived at with the Principle of the total input and the total Recovered. As per Deers assumptions, virtual purity of Molasses is that purity of Molasses which give Recorded Boiling House Recovery as per formula. B. H. Recovery is arrived at by using the value of virtual purity of Molasses in the Recovery Formula. We can ascertain Virtual Purity of Molasses as follows:—

* Suppose 100 is the Brix of J purity material entering in to the process. X is the total Sugar lost during the process in the left over solids. Virtual purity of Molasses

$$= \frac{X}{X + (100 - J)} \times 100 \quad (\text{i. e. } \frac{\text{Pol}}{\text{Brix}} \times 100)$$

This is the value of the purity of virtual Molasses which we have to put in the Boiling House Recovery Formula. The Value of X , i. e., total lost Sugar $= (100 - J) \frac{M}{100 - M}$.

This Shows that each nonsugar takes away $\frac{M}{100 - M}$ of Sugar, where M is the purity of Virtual

Molasses. This is the Principle of the concept of the Purity of Virtual Molasses in arriving at the Boiling House Recovery. The Recovery Formula as it is based on the principle of the purity of Virtual Molasses it is also proper to approach the Recovery Formula on this Principle.

The proof of SJM Formula :

Suppose 100 is the Brix of J Purity material entering in to the process. The recoverable Sugar is equal to $J - (100 - J) \frac{M}{100 - M}$ Where, M is the purity of Virtual Molasses.

$$= \frac{100J - JM - 100M + JM}{100 - M} \quad \text{and each non sugar takes away } \frac{M}{100 - M}$$

$$= 100 \frac{(J - M)}{100 - M}$$

of Sugar as per the concept of Virtual Molasses in arriving at recovery as explained above.*

$$= S \frac{(J - M)}{S - M}$$

Where $S=100$, The Purity of Sugar.

$$\text{And Recovery} = \frac{S(J - M)}{S - M} \times \frac{100}{J} = S \frac{(J - M)}{J(S - M)} \times 100.$$

Deers Proof of the SJM Formula is more Algebraic as per his unique other expressions.

be indicated by the purity of Virtual Molasses as follows :—

$$r_{85} = 100 - \frac{300 M}{17 (100 - M)}$$

(Where r is reduced B. H. Recovery and M is V. P. of Molasses)

The Importance of Virtual Molasses— Apparent Purity of Final Molasses is not dependable indication of Exhaustion as non-sugar composition of various samples varies. Virtual Molasses serves better in this respect. All process results are dependable on the purity of virtual Molasses. On any other basis if we try to explain process, it so happen that the same can be explained on the basis of the purity of Virtual Molasses, and it so looks that the explanation is based on Virtual Purity of Molasses only and the credit goes to Deer. It is such an important concept but its importance are left hanging. One of the well know Hand Books rejects to go in to the details of the subject taking it as unnecessary complications. The interest of younger generation is thus curbed. Unjustice mainly realised is but reflectable on Deer. Deer offered the concept and further preferred to evolve reducing recoveries. Actually his Reduced Recovery can

With the above background for the purity of Virtual Molasses as indicator, please allow me to offer the identity, E The Effective Boiling House Control to the Purity of Virtual Molasses.

E, The Effective Boiling House Control— All Boiling House Control is aimed at to reduce the total loss. Effective Boiling House Control is that control which is reflected to reduce the purity of virtual molasses, the indicator of Total Loss. Boiling House which reduces, Total Loss of Sugar to minimum is taken as 100% Efficient, Sugar to non-Sugar ratio in virtually exhausted virtual Molasses is to be taken as standard for minimum loss.

E, The Effective Boiling House Control. =

$$100 K \frac{(100 - M)}{M} \quad \text{Where } M \text{ is purity of Virtual Molasses.}$$

K = Sugar to Non-Sugar ratio factor in the Standarded Virtually exhausted virtual Molasses.

If K = 0.4 ; Following Virtual Molasses will indicate Effective Boiling House Control.

If Virtual purity of Molasses = 50, E = 40%

„ „ „ = 40, E = 60%

„ „ „ = 28.57 E = 100%

E, The effective Boiling House Control can be presented in terms of juice purity and Boiling House Recovery as follows : -

$$E = 10000 K \frac{(100 - J)}{J (100 - r)}$$

Following performances show the Effective Boiling House Control when $K = 0.4$

J	33 Mv.		44 Mv.		50 Mv.	
	(100-r)	E	(100 r)	E	(100-r)	E
90	5.47	81.25	8.73	50.90	11.11	40.00
85	8.69	81.22	13.87	50.89	17.65	39.99
80	12.31	81.23	19.64	50.91	25.00	40.00
75	16.42	81.21	26.19	50.91	33.33	40.00
70	21.11	81.20	33.67	50.91	42.86	39.99

It will be seen from the above results that The Effective Boiling House Control is constant at all juice purities when purity of Virtual Molasses is same, Further if we put the

Value of $(100-r)$ as $\frac{100 - J}{J} \times \frac{M}{100 - M} \times 100$ in the formula $E = 10000 K \frac{100 - J}{J(100-r)}$

the formula will be reduced to $E = 100 K \frac{(100-M)}{M}$.

This confirms the fact that the Effective Boiling House Control is constant at all juice purities when the purity of Virtual Molasses is same.

Special Features of the Indicator : Here we can accept that (1) Juices can be have as per their specific composition and we can treat juices as we can afford, (2) Sugar to non-Sugar factor in Virtually exhausted Virtual Molasses may be adopted different for different process keeping basis formula same for

all the processes (3) Magnified presentations of results are offered over wide range. The performances of high purity of Virtual Molasses and higher losses will be discouraged properly. (4) The Effective Boiling House control is indicated by the practical results of the performances without going for reducing recovery etc., and assumption. (5) Reduced Recovery is indicated by the Virtual Purity of Molasses and the performance orders of Reduced Recoveries are the same as per the orders of Virtual Purity of Molasses as Indi-

cator confirms the fact that the Purity of Virtual Molasses is the Virtual Indicator.

Virtual Efficiency of Boiling House

Deer has offered us a concept of analysing performances by Reducing Recoveries. Accumilated experience shows that it is easier to exhaust low purity juice to certain minimum purity of Virtual Molasses than to exhaust higher purity juice to the same purity of exhausted Molasses. More the difference in juice purities more it is felt. In general by some techonologists it is regarded that Reducing Recovery system favours low juice purity performances. Though Effective Boiling House control or Effective Boiling House Efficiency and Reduced Recovery are constant at all juice purities at the same purity of Virtual Molasses, Boiling House Efficiency varies with juice purities considering the same following is attempted to find out virtual efficiency of the Boiling House.

Boiling House Efficiency :—This is taken as the ratio of sugar recovered from the juice to the recoverable Sugar from the same juice when sugar to non-sugar factor, in the Virtual Molasses reaches the standard of Virtually exhausted Virtual Molasses. The Standard of Minimum loss. (This was known as Ideal Basic Recovery with Mv. 28.57).

Low purity juices are not favoured with the available range of recoverable sugar. So B. H. Efficiency varies with juice purities and B. H. Efficiency or B. H. Efficiency Reduced to standard juice purity should be discouragr d.

In practice we analyse various variables like Velocity, Atmosheric Temperature Humidity, Population Density, Sea Depths, etc., with Mean Values. In Sugar Factory control we go for expressions like Average crushing, Avarage Recovery etc., Then we can also go for Avarage or Mean Reduced Efficiency as avarage expressions are Virtual Values.

Virtual Efficiency of the Boiling House

V. E. Boiling House can be expressed with the following Formula.

$$E. \text{ The Virtual Efficiency of B. H. } = \frac{R_m}{e} \times 100$$

Where R_m = Mean Reduced Recovery (i. e. Recovery Reduced to Mean Reduced juice purity.)

e = Extratable Sugar from Reduced Mean Purity Juice when Sugar to non-sugar ratio factor in Virtual Molasses goes to standard of Virtually Exhausted Virtual Molasses. (i. e. Basic Recovery Reduced to Mean Reduced purity of Juice.)

Mean Reduced Recovery can be calculated with the following formula :—

$$\text{Deer, } R_m = r + \frac{100-r}{100-J} \times \frac{J_m-J}{J_m} \times 100.$$

$$\text{G.R. } R_m = r + \frac{K_m}{100-M} \times \frac{J_m-J}{J_m J} \times 10000.$$

where J_m = Mean Reduced purity of juice.

J = Juice purity of the performance.

r = Recovery of the performance.

M = Actual gravity purity of Final Molasses.

K = Non-Sugar in Clear Juice % Non-Sugar in Mixed Juice.

$$J_m = \text{Mean Reduced Purity of Juice} = \frac{85+J}{2}$$

e = Extratable Sugar, (Sugar to non sugar Factor in V. Molasses = 0.4)

$$(i) \quad e = \frac{14J_m - 400}{10J_m} \times 100$$

$$(ii) \quad 100-e = \frac{400 - 4J_m}{10J_m} \times 100$$

Following examples will show the Virtual Efficiency and Recoveries as follows :—

J	Mv	r	Jm	e	Rm	VE	R.B.H.R.	E.B.C.
80.78	32.13	88.74	82.89	91.74	90.23	98.33	91.64	84.49
82.36	32.13	89.86	83.68	92.21	90.76	98.44	91.64	84.49
83.87	34.91	89.68	84.435	92.63	90.11	97.27	90.53	74.58
84.64	35.16	90.16	84.82	92.84	90.29	97.25	90.43	73.76
84.05	33.95	90.25	84.525	92.67	90.59	97.74	90.92	77.81
82.90	34.56	89.11	83.95	92.35	89.90	97.35	90.68	75.74
73.93	32.12	83.31	79.495	89.66	87.77	97.88	91.65	84.65

Above examples exhibit following facts :—

(i) Boiling House Virtual Efficiency is indicated by the purities of Juice, Virtual Molasses and by the purity of Virtually exhausted virtual Molasses as per given General Formula :—

$$E = \frac{Jm - Mv}{100 - Mv} \times \frac{71.43}{Jm - 28.57} \times 100$$

(ii) When Purity of Virtual Molasses is same reduced recoveries remain same irrespective of juice purities.

(iii) Boiling House Virtual Efficiency is

realised higher, when purity of Virtual Molasses remains same or goes low with runs of increase in juice purities and Virtual Efficiency is realised lower when purity of Virtual Molasses remains same or goes high with performances of lower purity juices.

Special Features

Performances of all jusices will remain linked while arriving at the results of The Virtual Efficiency. Better consideration is offered for the performances of all purity juices in the recovery of sugar from the available range of recoverable sugar considering

the case of achieved purity of Virtual Molasses.

Conclusion

Both the above systems, that is The Effective Boiling House Control and The Virtual Efficiency of the Boiling House are preferable to the recovery Analysis Procedure. Deers

concepts of the Virtual Molasses and the procedure of Reducing Recoveries will be thus best utilised.

I am grateful to Shri. S. N. Gundu Rao as his papers inspired me to go into the details of the subject. I am also grateful to the Management of Salar Jung Sugar Mills, Munirabad for their kind encouragements.

PREVENTION OF SPONTANEOUS COMBUSTION OF MOLASSES A CASE STUDY OF THE PHENOMENA IN TWO SUGAR FACTORIES IN INDIA.

By

S. K. D. Agarwal, Km. Veena Gupta and J. K. Srivastava

ABSTRACT

Spontaneous combustion of molasses is being reported from all over the world in the last 70-80 years. The description of the happening has been described in quite good detail by a large number of workers, including the measure that could lead to prevention of ignition yet the process has baffled solution. In this phenomenon the molasses undergoes extensive foaming with sudden rise in temperature of the whole material followed by overflowing of the molasses and ebullition of pungent fumes leading to ultimate self ignition of the molasses to solid porous carbonized material after explosive violence. Existing theories and contemplations that can likely be responsible for the phenomenon have been received and discussed in light of the case study of the same at Yamunanagar in Jan. 1975 and Balrampur in April, 1978, where the temperatures of the molasses rose considerably leading to fall in brix and purity. Studies made in the laboratories showed that the process was very much possible as was evident when the temperature was raised. This led to quick forthright and spontaneous combustion. A critical examination for simulating the phenomenon showed that caramel as produced by burning of the sugar could very well initiate the reaction. The supposed role of high amino acid content was examined and it was indicated that Maillard reaction or melanoidin formation, which acquired staggering proportions was possible after the temperatures have sufficiently increased inside the molasses. This reaction was thus showed to accelerate the process after it has set up in advance and temperatures have sufficiently risen. A series of antifoaming reactions proved futile while turkey red oil was found useful both as antifoaming agent and also for quenching the reaction. This material was actually tried for its efficacy in the two factories

with good success. It was shown that the molasses when treated in such a way did not burn even after 20 to 30 hours of heating at 90°C while that molasses which was prone to the possibility of ignition showed frothing and burning within one hour or two. It was therefore suggested that the molasses heating at the weighing and pumping stage may be done by exhaust steam only since live steam can cause sufficient caramelisation of sugar, by contact and provide necessary stimulation.

Introduction

Spontaneous combustion of blackstrap molasses has been reported from a large number of factories spread all over the world. The deterioration of molasses in storage is, however, not to be intermingled with the phenomenon of spontaneous combustion, inspite of certain common features. The subject of deterioration in storage has been the subject of a large number of studies from over 60-70 years as studied by Browne¹, Geerligs², Kopfler³, Habib⁴, Hucker⁵ and Paderson and a large number of other workers^{6,7}. It is now well recognised that different molasses behave differently and the rate of deterioration during storage can be a very slow as well as quite fast as well. These may undergo changes in composition as a result of internal chemical reaction, such as oxidation and reduction. At times this deterioration is quite slow but at others it may be very fast even, leading to its spontaneous burning as a result of internal reactions, wherein loss of sugar occurs to various extents. An excellent and exhaustive review on the stability of the molasses on storage is given by Owen⁶ and by Saba⁷ and co-workers.

Of late, the phenomenon of spontaneous combustion of molasses are being reported

quite frequently. In this, the molasses in storage undergoes extensive frothing and increase of temperature, so much so that, if undetected in the initial stages, the molasses starts flowing out of the storage tanks from all over, accompanied with copious emission of hot pungent fumes, leading to sudden and violent decomposition and self ignition of molasses to a solid state of porous carbonized mass after explosive, violence.

Case Study of Certain Occurrences

Fromen⁸ and Bowland reported a case of Central Fajardo in Puerto Rico in June 1953 after 48 years of operation of the factory without such an occurrence in any earlier years. Olbrich⁹ has reported ten such occurrences between 1922 to 1939 in Egypt, two in Hawaii in 1953, two in Puerto Rico (1952, 53) one in India (1953) one in Brazil (1963) and one in Peru (1961). A large number of cases of spontaneous combustion and froth fermentation, as it is often called, have been reported from India recently, some of which are as listed below :

1. V. V. S. Sugars, Chagalluu, Andhra Pradesh, in April, 1969.
2. Balrampur Sugar Mills, U. P. in 1969

and 1977, and its possible occurrence in 1978.

3. Saraswati Sugar Mills, Yamunanagar, Haryana in 1971 and 1974 and possibility of the same in 1975.
4. Amaravati Cooperative Sugar Mills, Coimbatore, Tamil Nadu in October, 1971.
5. Batala Cooperative Sugar Mills, Batala, Punjab in 1974.
6. Sree Bileshwar Khand Udhog Khe-dut Sahkari, Mandli, Gujarat in March 1975.
7. Rahuri Sahkari Sharkar Karkhana, Maharashtra in May 1975.
8. Shree Satpuda Tapi Parisan S. S. K. Ltd., Maharashtra in 1974-75.
9. Sasamusa Sugar Mills, Bihar in April, 1977.
10. Mawana Sugar Works, U. P. in May, 1974.
11. Ravalgaon Sugar Farms, Maharashtra in May, 1974.
12. U. P. State Sugar Corporation, Bhatni, 1978.

A short history of some of the occurrences is given below bring out the magnitude and severity of the problem.

Fromen and Bowland reported occurrence in blackstrap molasses in June 1953 in tank

Nos. 2 and 3 only, when a rather heavy and muffled frothing of explosive nature emanated from within tank No. 3, when the molasses overflowed the top of the tank through the vent space apparently due to sudden and very powerful reaction of decomposition, which was accompanied by furious agitation and ebullition and very rapid generation of intense heat, when great volumes of steam and acrid vapours poured from the vent space. The water of the molasses quickly evaporated and the overflow subsided when the inside mass lost its fluidity. High temperatures continued for 48-72 hours. Spraying of large volumes of water with the help of heavy duty pumps prevented buckling of the plates of the molasses tank. In tank No. 2, out of 924,000 gallons of molasses, hardly 30 to 40,000 gallons of molasses could be saved and the rest pumped out to the sea when the temperature rose to 140° F. The temperature then dropped down automatically and the ignition did not occur.

In India, the phenomenon has been reported both from sulphitation and carbonation sugar factories making direct consumption white sugar. Yamunanagar reported the phenomenon of May 1971 from the time molasses started flowing out of the masonry storage tank from all the sides. The flow increased within 30 min. and the temperature rose rapidly. After a shortwhile copious emission of hot pungent fumes was observed and it was feared that it may burst into flame. Fire fighting equipment was employed to dilute the molasses at the rate of 50,000 gallons per hour which was poured to bring down the temperature to 87°C, which could

stop the evolution of fumes. The purity of the molasses at this stage was 2%.

Amaravathi reported the spontaneous combustion from open pit in October, 1971 after 11 years, when quite a good amount of froth developed which flowed out from the sides leaving hard black solid mass with solid liquid material at the base of the pit.

Mawana reported burning of about 40,000 quintals of molasses stored in mild steel tanks. Batala factory, which experienced excessive foaming in the syrups during the season reported spontaneous combustion during summers in the tank having 12 ft. depth of molasses and conversion of the whole molasses into charcoal like mass.

Jain¹⁰ has reported a case study of the phenomenon that occurred during May, 1974 at Ravalgaon after a lapse of 14 years in spite of following the same technique of manufacture during all these years. Smell of acetic acid was experienced during intensive frothing and rise of temperature. It was interesting that in spite of everything in common, the molasses of 3 out of 6 pits were only carbonized and the rest behaved in the normal fashion.

Existing Theories and Considerations

A large number of workers¹¹ have advanced many explanations and theories for the spontaneous combustions. Browne has suggested that the sugar products may undergo changes in composition as a result of internal chemical reactions, as a result of reaction between unstable organic substances and the sugars, leading to the conversion of sugar into

dark coloured humin like substances of high carbon content preceded by violent eruption. The degree of liming caused variation in molasses stability. Meades¹² and Chen, who have reported a large number of such occurrences from various countries reported only common condition as high heat of storage, which was in line with the hypothesis advanced by Fromen and Bowland, who attributed it to overheating of molasses to 125-145°F before storage at 105°F. Chen¹³, found that those molasses which went into ignition had higher initial nitrogen content. A large number of workers^{14,15}, have reported excessive amino acid content in those molasses that underwent spontaneous combustion and attributed it to the melanoidin formation or Maillard reaction as a result of reaction of amino acids and reducing sugars present therein, into a complex series of reactions, which eventually resulted in the evolution of carbon dioxide. All the suspicious molasses were reported to have a distinct reddish colour. Berliner¹⁶ and Staff who compiled work of a large number of workers and their observations, attributed the phenomenon to the action as a result of intense sun during long summer months in pits and it was reported that the molasses stored in tanks did not undergo this violent change. It was also reported that during the occurrence, the temperature at the surface was 30°C higher than at the base and the purity of the molasses at the surface was also half to that at the base of the pits. Trivett¹⁷ claimed that foaming molasses can be controlled to a degree by the use of certain surface active substances or by introducing compressed air into the mass of the molasses. Owen¹⁸ indicated that

dilution of low grade molasses, reboiling, skimming and cooling before storage resulted in a considerably more stable molasses.

Sharkara¹⁹ has compiled a comprehensive collection of the existing theories based on the work of different workers. It is reported that this kind of decomposition is not the result of microbiological action but is a spontaneous decomposition of complex non sugars with the formation of carbondioxide, which is an exothermic reaction and occurs only at high temperatures. The unstable molasses showed higher amounts of total solids, organic non-sugars, total nitrogen and nitrate nitrogen. The reaction is the results of the formation of highly labile unsaturated organic non sugars high carbon content as a result of dehydroxylation. The mineral salts in low purity molasses play an important part. The continued stripping-off of the hydroxyl groups from the sugar molasses leads not only to the loss of total sugars but also to the accumulation of unsaturation carbon compounds of high exothermic reactivity. When this stored up energy starts releasing, the temperature which is already high begins to increase rapidly with the loss of more and more combined water, until finally, by sudden internal chemical readjustments, the whole mass, with almost explosive violence is converted into a porous cake like carbon. The decomposition is favoured if the low purity molasses is alkaline in reaction, over concentrated, overheated before storage and stored in open tanks exposed to hot sun.

Present Study

One of the most burning problem of the

centuary has been the spontaneous combustion of molasses, which has defied all solutions inspite of wide range of investigations undertaken the world over. It is interesting that inspite of formulation of many theories for the occurrence of the phenomenon, under identical conditions of working of the factories, the climatic conditions and storage, the phenomenon is rare in occurrence and not reported under identical conditions in all other respects in the same factory, for the same year and for different storage tanks, storing the same material. Inspite of advancement of several theories for commencement of the phenomenon or the preventive measures likely to be helpful, no case has been reported from anywhere in the world that the reaction, once initiated could either be prevented or controlled. The preventive measures that have been reported (*vide infra*) from time to time are based on the steps that were taken to slow down the ultimate reaction, and have yet resulted in near total loss of the material in most of the cases. The phenomenon could neither be simulated. The work reported in this communication deals with the studies undertaken at two sugar factories, one in January 1975 at Yamunanagar in winter month and the other at Balrampur in April, 1978 in the summer, where the temperature of the molasses started rising and reached the range of 55 to 60°C (130 to 140°F) and it was feared at both the places that spontaneous combustion of molasses would take place. It may be a coincidence that both the places, the phenomenon was observed a year earlier. The work reported in this communication deals with the steps taken in the factory and also in the laboratories of NSI, Kanpur for

simulating the phenomenon or its after effects.

Case History of Yamunagar (1975)

It was a carbonation factory following middle juice carbonation process. The factory had three steel tanks and one masonry tank. The capacities and dimensions were

	Quintals	Dia	Height
Steel tank No. 1	23720	56' 6"	22' 6"
Steel tank No. 2	42700	62' 7"	33'
Steel tank No. 3	29240	51' 5"	33' 6"
Masonry tank	29300		

The factory was employing live steam at a pressure of 130 to 150 lbs./per sq. in. for pumping and consequent dilution (a) below the centrifugal machines for pumping to the weigh bridge, and (b) at the weight bridge. The brix of the molasses before pumping was 97-99, while after the two pumping near about 94. The molasses had to be pumped either to the masonry tank near the weigh bridge or to the steel tanks. The farthest distance to be covered was more than 700 ft. plus a height of about 35 ft. to make it fall from the top of the tanks. The hot molasses dropping over the molasses already in the tank caused considerable turbulence and generation of the froth.

The heating being done with live steam resulted in the increase of temperature and

the dilution of the molasses to enable the molasses to flowthrough the pipe lines. The temperature was recorded at both the places. It was 42 to 45°C below the centrifugal machines. During the first heating, it rose to 53 to 55°C and after the second heating to 64 to 66°C.

The brix of the molasses during various weeks of November, December and January preceeding the investigations was found to vary from 93.8 (minimum) to 95.05 (max.) with an average of about 94.8.

The molasses from one of the tanks showing tendency of frothing was examined. The samples were examined. The samples were obtained from the bottom and the top layers. These showed the following analysis.

	Brix	Pol	Purity
Bottom	92.56	32.4	34.78
Top	90.61	31.2	34.43

The brix fall was therefore considerable. The molasses showed tendency of separating into two layers as a result of frothing.

The bottom and top layers of the molasses were examined in the laboratories of the factory. These were stored in a series of cylinders in an oven maintained at a temperature of 88°C. It was found that both the molasses showed vigorous frothing and the volumes increased to 4 folds in the bottom and top layers in 2 and 3 hours respectively. Old molasses of the factory, on similar heating did not show any tendency of frothing and the volume of the molasses increased hardly by 25% of the initial volume as result of heating. Some samples of the factory molasses were brought to N. S. I. and they also indicated similar tendencies.

Two commercial surface active compounds, diesel oil and turkey red oil were employed in the same oven in the next set of experiments in the factory's laboratory to study their suppressive behaviour on the foam. While the surfactant employed did not work at all, diesel oil delayed the period of frothing by 50% but the reaction continued unabated thereafter as well. The use of turkey red oil, however, proved as a boon. Laboratory studies showed that in the initial stages, the froth rose

by about 20 to 25% by volume, but further rise did not occur. Rather the froth level fell thereafter and the frothing could not be observed inspite of heating for 7 to 8 hours in the oven. The use of turkey red oil in the factory thus prevented further frothing other measures adopted in the factory will be discussed in this communication later.

Detailed investigations on this problem were delayed for want of a timely report of a similar nature, which was taken up in an exhaustive manner in the Balrampur Sugar Factory in April, 1978.

Case of Balrampur Sugar Factory

Balrampur is a sulphitation factory. It faced spontaneous combustion of molasses during April, 1977 and when the temperatures started rising, the fear loomed large.

The factory had two steel tanks and a masonry tank. While the molasses of the masonry tank, which was filled to the brim during the season was behaving in the normal manner, without any rise in temperature the molasses of the steel tank behaved differently. The capacities and dimensions were as under :

	Quintal	Dia	Height	Dimensions
Steel tank No. 1	10,4000	40'	25'	—
Steel tank No. 2	10,400	40'	25'	—
masonry tank	17,340	—	—	33.5x13x2.9 meters

The molasses of day to day production was being pumped in tank no. 2 during the observation of the frothing. The steel tanks were by the side of the spray pond and it was just a chance sequence, that the direction of the wind was carrying water spray direct on the steel tanks. In addition, the tanks were being cooled by rubber hoses since 20th April, 1978. A recirculation pump was also installed in one of the tanks, being fed with molasses of daily production.

The brix of the molasses being pumped was generally of the order of 91 to 93 as may be seen from Fig. 2, Curve A. It was interesting that within the short interval, the brix of the molasses fell considerably by 5 to 7 units at times as may be seen from curves B and C. It may be of some importance to quote that the boiling practice during the season for the final massecuite was not altered, yet the average brixes were higher for the earlier months, which were as below :

	Brix	Pol	Purity
December 1977	93.83	35.43	37.76
January 1978	94.11	35.30	57.51
February 1978	93.11	35.66	38.33
March 1978	93.40	34.92	37.88

Normally, it was anticipated that the purities of the molasses would show a rising trend with the approach of the hot summer months, yet interestingly the brixes showed a falling

trend for the definite and the purities of the fresh molasses were also on the lower side, being only from 35 to 37, which showed that the molasses under production itself was undergoing changes of self destruction of the sugars, resulting in loss of brix and purity.

The factory reported rise of temperature in the steel tanks from 15th April onwards. Because of the cooling of the walls of the steel tank from all the sides by the cold water, and the spray from the spray pond the recirculation of the molasses with the help of a pump, the temperature inside the molasses could be controlled for about 12 days between 50 to 53°C. When the investigation started on 28th April, the temperatures in tanks No. 1 was reported to be 60° C and in tank no. 2 at 53°C.

It was found on going through the record of the molasses that the purities varied from 35 to 37 during the last 15 days (see Fig. 1, curve A), purities of 38 to 39 were also reported for some shifts during this interval. In spite of filling tank no. 2 with fresh molasses daily production, the purities as low as 32 to 33 were also recorded in tank no. 2 on 22nd, 24th and 26th April (see curve B). As the molasses from the bottom of the tank was being recirculated the purities throughout the tank were expected to be the same. The observance of such low purities show the loss of sugar. The total quantity of molasses at this period was 6000 qts. and the height of the foam over this molasses was roughly 3 to 4 ft. Curve C indicated the change in purity of the molasses stored in tank No. 1, which had about 2500 qts. of molasses and the recorded purities were as low as 28 to 29 only.

Fig. 3 gives the variation in the temperature of the steel tanks Nos. 1 and 2. It was reported that temperature in tank No. 2 rose to 60°C on 24th and in tank No. 1 to 60°C on 27th April. After quenching the reaction (vide infra) by the evening of 28th April, a remarkable fall in temperature was obtained by 29th evening by which the temperature could be stabilised at 41 to 42°C in tank No. 2 where fresh hot molasses from the routine production was being pumped and to 38°C in tank No. 1, where the recirculation of molasses was also done from 28th. It was learnt from personal communication that the temperature did not rise thereafter.

A study of the working of the molasses pumping in the factory showed that live steam at a considerably reduced pressure (with respect to that was in use in Yamunanagar) of 30 to 50 lbs. per sq. in. only was being employed for heating the molasses as in the earlier factory. The highest temperature recorded inside the factory during pumping was 68 to 70°C, though usual pumping temperature was reported to be about 55 to 60°C only. It was also noticed that steaming below the centrifugals was sufficient to carry on the pumping at 55°C.

Examination of the Behaviour of the Molasses in the Factory's Laboratories

On lines of the work done in the Yamunanagar sugar factory, the behavior of molasses was studied at Balrampur also. A series of tall cylinders of one litre capacity, were taken and in each 200 ml of molasses was placed in 4 cylinders. The molasses that was taken as control rose rapidly in the cylinder for the first

one hour, when the volume of the molasses including the foam rose to about 260% of the initial volume (see fig. 4 curve A), where after the molasses started burning and only carbonaceous mass was left over. In the second cylinder, where a known volume of turkey red oil was mixed thoroughly in the molasses, the volume increased only marginally (see curve B) by 50% of the initial volume after about 150 mins, whereafter it did not rise. The molasses did not burn inspite of keeping it for 4-5 hours. One of the commercial surface active substance available in the factory was also tried alone and alongwith turkey red oil. The surfactant alone was not found effective, while worked alongwith the oil in quenching the reaction effectly as the oil worked alone as well. Desired quantities of the oil, whose dose has to be evaluated under the factory's condition and which was found to be 20 p. p. m. at Balrampur, was added on 28th evening in both the tanks; where recirculation of molasses was kept on and it was found that the reaction stopped completely by 29th evening, when the temperatures in tank No. 1 and 2 would be brought down to 38 and 42° C respectively (see fig. 2), whereafter the temperatures did not rise.

The foaming tendency of the treated molasses was got examined in the factory's laboratories. The data is returned in Fig. 5, when the molasses of tank No. 1 and 2 were subjected to heating under similar conditions. No further additions were made to the molasses but for prior mixing of turkey red oil as already discussed above. The molasses were heated for a period of 20 hours. The molasses tank No. 1 showed an approximate increase in

volume (including the foam) by about 10% only in 8 to 10 hours and by 15% in 20 hours, while the molasses of tank 2 showed a rise in volume by 20 to 25% in the first 8 to 10 hours and by about 45% in 20 hours. This behavior was akin to that observed by the authors in all earlier studies for ordinary molasses samples. No burning of the molasses occurred in either sample inspite of the vigorous treatment confirming to the achieved stability of the treated molasses. The purities of the molasses in the tank No. 2 for the next 3 days, were 33.82, 34.86 and 33.88, which also confirmed to the achieved stability.

Simulation of the phenomenon and critical examination of the existing theories

Though various theories have been propounded as discussed earlier for the occurrence of the spontaneous combustion, no work has been reported for any molasses which could be subjected to the phenomenon of either froth formation or ignition in the laboratories. The authors studied a large number of permutations and combinations spread over a period of over a decade and felt that the factors primarily responsible for the process could be caused to certain degree only by the processes of caramelisation as produced by heating or burning of sugar and the melonoidin formation, on which a large volume of work has been reported by the authors 27-29 already.

The molasses of Balrampur Sugar Factory, obtainable after quenching the reaction was subjected to the simulation of froth fermentation conditions by extreneous addition of the following substances.

- A. Different amounts of Caramel as prepared by heating sugar in solid state at $210 \pm 5^\circ\text{C}$.
- B. Caramel as prepared by heating 5% glucose solution with 1.0% sodium hydroxide at 70°C in a thermostatic bath and concentration the solution thereafter under vacuum at 40°C .
- C. by the strenuous addition of different amount of glycine, aspartic acid and α -amino butyric acid.

Such molasses were then subjected to heating at $90 \pm 1^\circ\text{C}$ in an oven in the laboratories of N. S. I. Kanpur. One sample was kept as such for control purposes also. The frothing as observed during the course of heating followed the pattern shown in Fig. 6, showing the increase in the volume of molasses alongwith the foam. The figure has been subdivided into two portions, the lower one showing the influence of heating the molasses as such (control) and alongwith different types of caramels, while the upper portion of the figure indicated the effect with three selected amino acids, viz. glycine, α -aminobutyric acid and glutamic acid as aspartic acid.

It may be seen that the molasses when heated as such (curve A) showed only marginal increase in volume for some period by say 10–12% of the initial volume and then the volume fell and acquired a constant level, which did not increase on further heating. The increase in volume may practically be because of the observance of the initial volume at room temperature of $32\text{--}33^\circ\text{C}$ and later at the temperature of the oven of 90°C plus slight frothing. Addition of 1.0 gm of caramel

as prepared by heating glucose with caustic alkali did not produce any impact on the molasses volume (see curve A_1) which coincided with control set. Curves B, C and D corresponded with the addition of 1, 2 and 4 gms. of solid caramel prepared by direct heating of sugar to 200 ml of molasses and thorough mixing before heating in the oven. The increase in volume was caused by the frothing. The maximum increase in volume was 50% only on addition of 1 gm of caramel within 120 minutes, whereafter the frothing decreased and the volumes stabilised after 4 hours at 15%. Addition of 2 gms. of caramel caused further increase in frothing which remained foaming for a further period of 90 minutes, whereafter only the volume fell and stabilised 15% or a little more, while addition of 4 gms of the caramel caused additional increase and for longer interval and subsidised thereafter. This showed that the production of caramel as a result of heating of sugar helped in increasing frothing, which if not controlled could result in more and more frothing. The upper portion of the figure showing influence of 3 amino acids also showed selective influence. Addition of 1 gm of glycine to the molasses did not cause any perceptible increase in frothing (Curve E), while addition of only 0.5 gm of α -aminobutyric acid caused sufficient increase in foaming. The volume increased rapidly for the first 2 hours or so, whereafter acquired a constant value for another 100 minutes, but fell thereafter to a volume, which was akin to the molasses on heating as such in control, experiment. Addition of 2.0 gm of aspartic acid caused even greater increase in frothing. The increase in volume was faster for the first 4 hours and fell sharply thereafter. It may be pointed out here that the faster rate

showed by aspartic acid was because of greater amount of the amino-acid employed.

The reaction of amino acids with the reducing sugars is well anticipated. These amino-acids are present to different extents in the cane juices and are carried even to the molasses to different extents. The primary product of reaction of reducing sugar and amino acids are generally considered ²⁰ to be N-glycosides, which are reducing in nature and can be readily hydrolysed by acids to give the original compounds. However, on continuous heating the condensation products turn yellow through orange, brown and reddish coloured substances, especially at high concentrations of the reactants leading to the formation of brown or black amorphous substances termed as melanoidins²¹. The reaction with most of the aminoacids is considered similar in reaction through Amadori²² rearrangement or Strecker²³ degradation.

Amino acids are present in the cane juices, which have been determined from time to time. Zerban²⁴, made qualitative investigation and detected presence of asparagine, glutamine, aspartic acid, glutamic acid and a few more amino-acids. Robert²⁵ and Martin

made quantitative investigations of about 20 amino-acids in Louisiana cane juices bearing aspartic acid 0.16%, mixture of asparagine, glutamic-acid and serine 0.57%, alanine 0.07%, aminobutyric acid 0.04%, proline 0.03%, valine isoleucine, lysine 0.02%, glycine 0.01% etc. Wiggins²⁶ and Williams also made such studies for estimation of total amino acid content of the juices, which was employed by the author²⁷⁻²⁹, for investigation of amino acid content of the juices of Gola, Palia and neighbouring factories for a series of years. It was found that the aminoacid content of Palia juices and for some regions of Gola was 50% to 100% higher to the neighbouring factories. The amino acids identified included aspartic acid, glutamic acid, glycine, histidine, α and β , alanine, isoleucine. It was of particular interest to point out from chromatographic studies that no single amino acid could be eliminated during clarification and processing and all of them were retained till the molasses stage. It is of interest to point out that 11 different amino acids could be detected at Palia, while only nine at Kanpur and only eight at Balrampur. The Rf values were as given in Table 1.

Table—1

Rf values of amino acids detected in different factories

Spot No.	Gola	Palia	Kanpur	Balrampur
1	0.0	0.0	0.0	0.0
2	0.012	0.013	0.014	0.007
3	0.036	0.036	0.036	0.017
4	0.052	0.05	0.054	0.032
5	0.083	0.084	0.083	0.083
6	0.115	0.112	0.122	0.136
7	0.148	0.146	0.145	0.16
8	0.175	0.172	0.216	0.30
9	0.219	0.222	0.22	—
10	0.235	0.230	—	—
11	0.358	0.360	—	—

It may be seen that some of the sports were new, the identification of which is under investigations. However the total amino acid content was about 1500 mg/l on 100 Bx at Balrampur as at Kanpur, while the quantities at Gola and Palia were still higher.

The rate of reaction of some of the amino

acids, which are dominantly present were examined³⁰ in pure systems at a brix of 15° having 0.6 M conc. of glucose and the amino-acid at 95°C and pH 7.5. The time required to obtain the colour density corresponding to that of molasses having values at 490 and 560 nm as 0.60 and 0.20 approximately, were as under :

Amino Acid	Time in minutes
Asparagin	240
Aspartic acid	260
Glutamic acid	210
alanine	250
r-aminobutyric acid	60

The above results showed that the rate of reaction varied with the acid and was fastest for r-aminobutyric acid as was evident from the result presented in Fig. 6, when only 0.5 gm. of the acid could yield roughly the same impact on molasses frothing as was given by 2.0 gm. of aspartic acid. It may also be pointed out that the reaction with amino acids was prominent above a temperature of 80°C as may be seen from Fig. 7, showing the time required to obtain the same colour intensity on reaction of glucose with glycine. These

result showed that the amino acids present in molasses would result in increased reaction, when the temperature crossed over 80°C, but were hardly capable of initiating the reaction of frothing of molasses. The extent of amino acids present in the factory molasses was thus not capable of initiating the reaction.

The overall fall in purity as a result of heating of Balrampur molasses as observed in the laboratories with different reactants was as below :

Sample	Purity
1. Molasses as such without heating	30.37
2. Molasses having 1 gm of Caramel B	29.28
3. Molasses having 1 gm of caramel A	27.98
4. Molasses having 2 gm of caramel A	27.02
5. Molasses having 4 gm of caramel A	27.02
6. Molasses having 1 gm of glycine	28.50
7. Molasses having 0.5 gm of r - aminobutyric acid	28.12
8. Molasses having 2.0 gm of aspartic acid	27.23

It may thus be seen that at higher temperature both caramel produced by heating sugars as such and the amino acids can cause sufficient increase in frothing as well as loss of purity, while caramel produced by reaction of reducing sugars with alkalies worked as if it is heating of the molasses as such without any extraneous addition and had hardly any impact on the system. Even at lower temperatures the caramel produced by heating sugar caused increase in frothing and loss of purity to measurable extent. It may therefore be said that the most of the initiation of the reaction could be attributed to such a caramel. After the temperature have increased beyond 80°C or more especially near 90 to 100°C, the presence of aminoacids may cause sufficient acceleration of the reaction leading to fast release of heat and frothing and also consequent reddish tinge in the molasses as reported by earlier workers.

While presenting reports of the advisory visits to Yamunanagar in Jan Feb. 1978 and in April, 1978, the authors therefore suggested to the factories that the heating of the molasses at 130-150 lbs/sq. in. at the former and 30 to 50 lbs/sq. in. the latter was primarily responsible for frothing generated in those molasses. It was then suggested that steaming

may be done at reduced pressures of 5 to 20 lbs/sq. in. or by exhaust steam, which would be ideally suited for the purpose of heating to enable the molasses to be pumped off. It may necessitate more heating surface to the provided for. It was also suggested to have an additional tank over the molasses tank having 24 hours molasses producing capacity which would be quite useful. After filling this tank for a day, whereby sufficient cooling would take place, the molasses may be dropped inside by the side of the wall of the steel tank with the help of the wide mouth opening, so that hot molasses already present in the tank may be least disturbed. This would avoid foaming because of the fall of the heavy liquid from a height and prevent occulsion of air bubbles inside the molasses layer.

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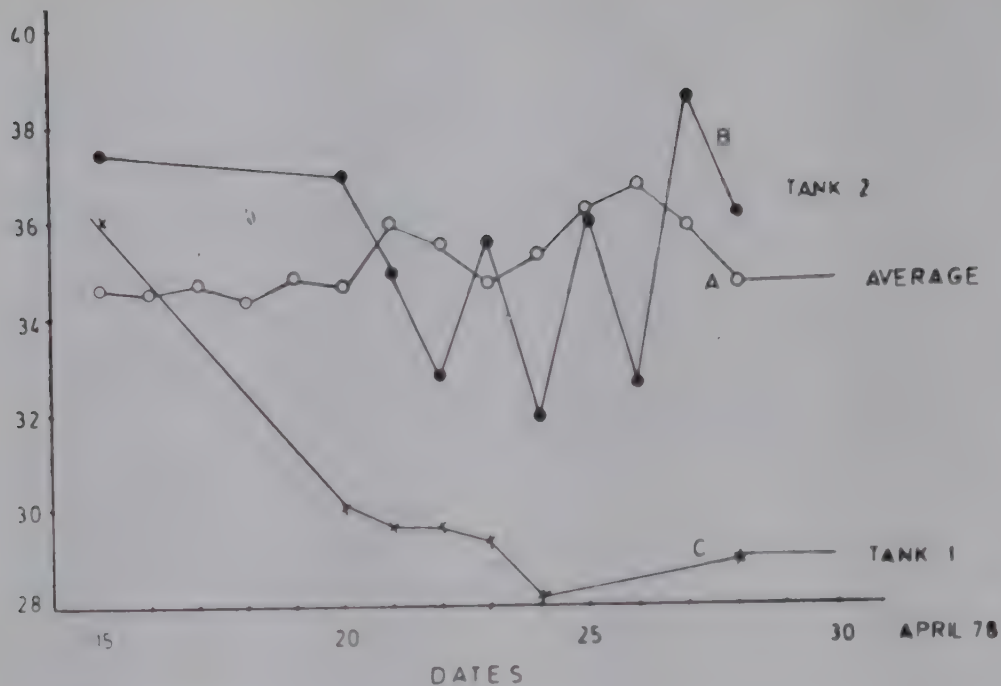


FIG 1 VARIATION IN PURITIES PRIOR AND AFTER CONTROL OF SUSPECTED PHENOMENON OF SPONTANEOUS COMBUSTION

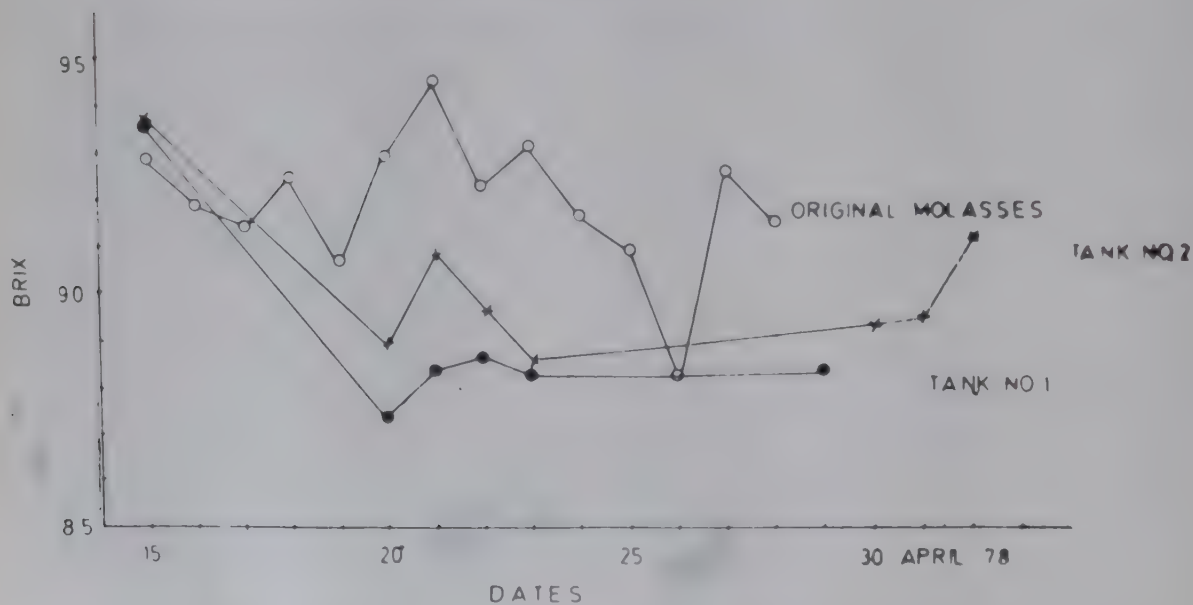


FIG 2 LOSS OF BRIX DURING THE PHENOMENON AND ITS CONTROL

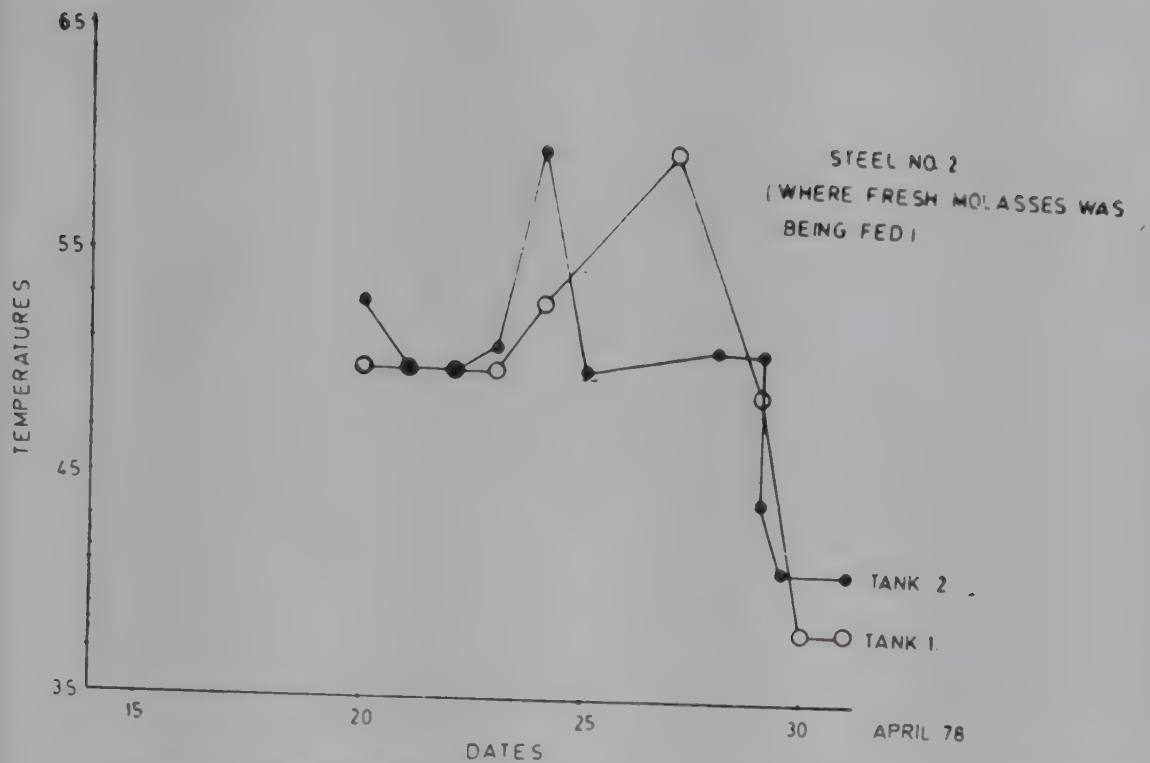


FIG 3 VARIATION IN TEMPERATURE DURING AND AFTER CONTROL OF SUSPECTED PHENOMENON OF SPONTANEOUS COMBUSTION

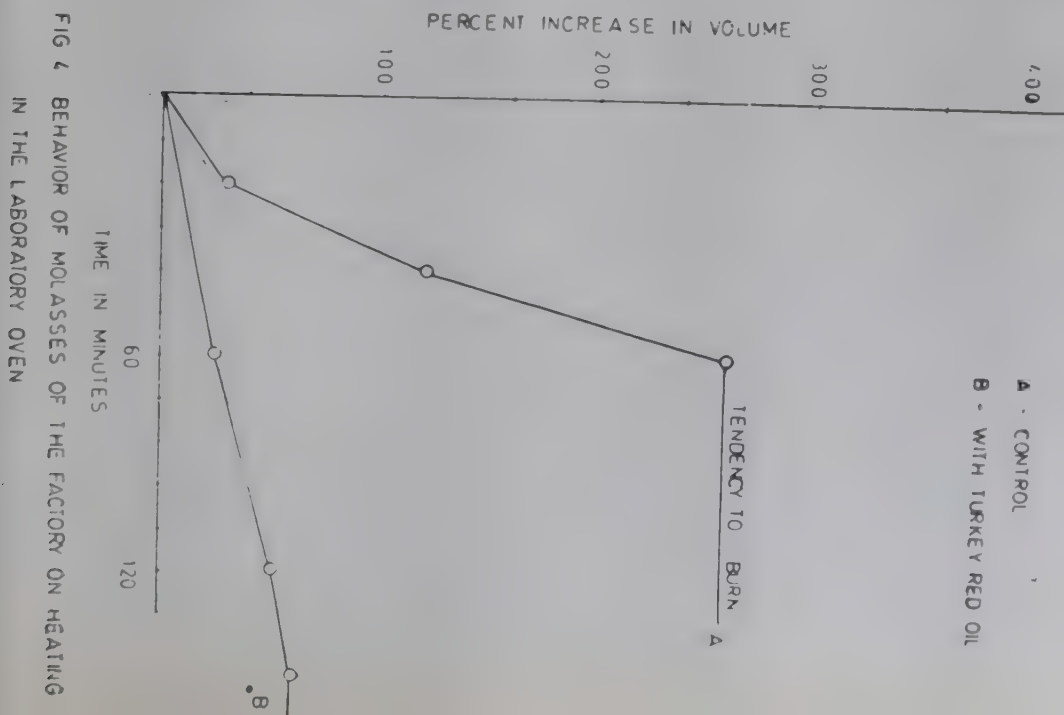


FIG 4 BEHAVIOR OF MOLASSES OF THE FACTORY ON HEATING IN THE LABORATORY OVEN

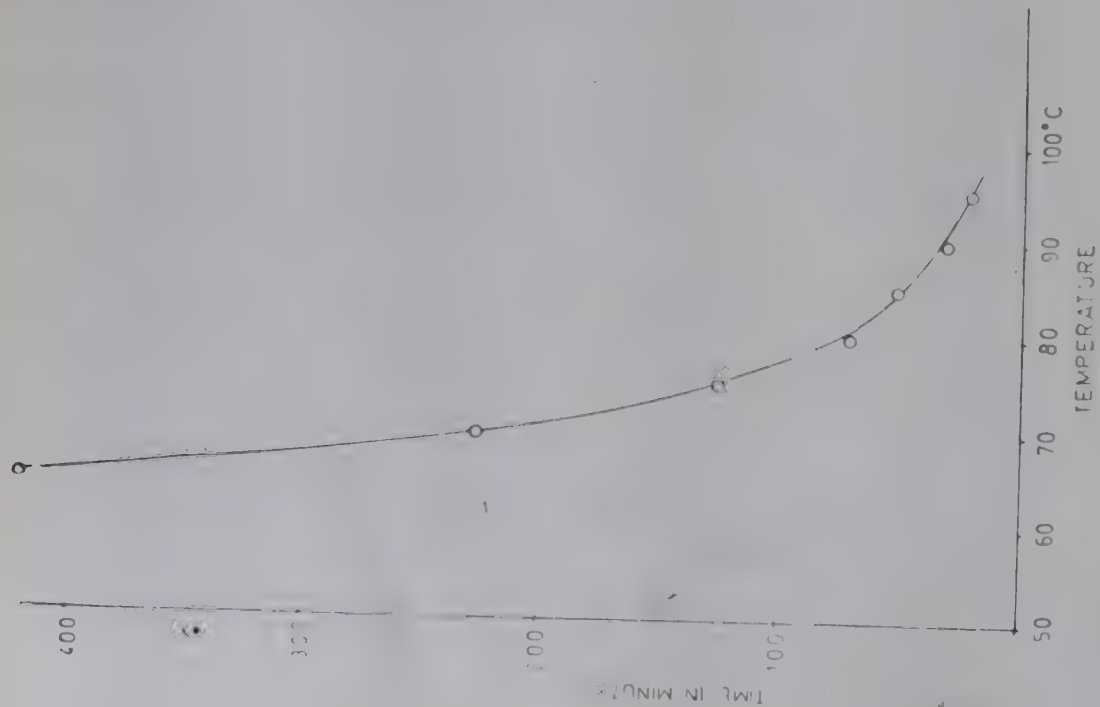


FIG 7 TIME REQUIRED TO OBTAIN MOLASSES COLOUR BY REACTION OF GLUCOSE WITH GLYCINE AT VARIOUS TEMPERATURES

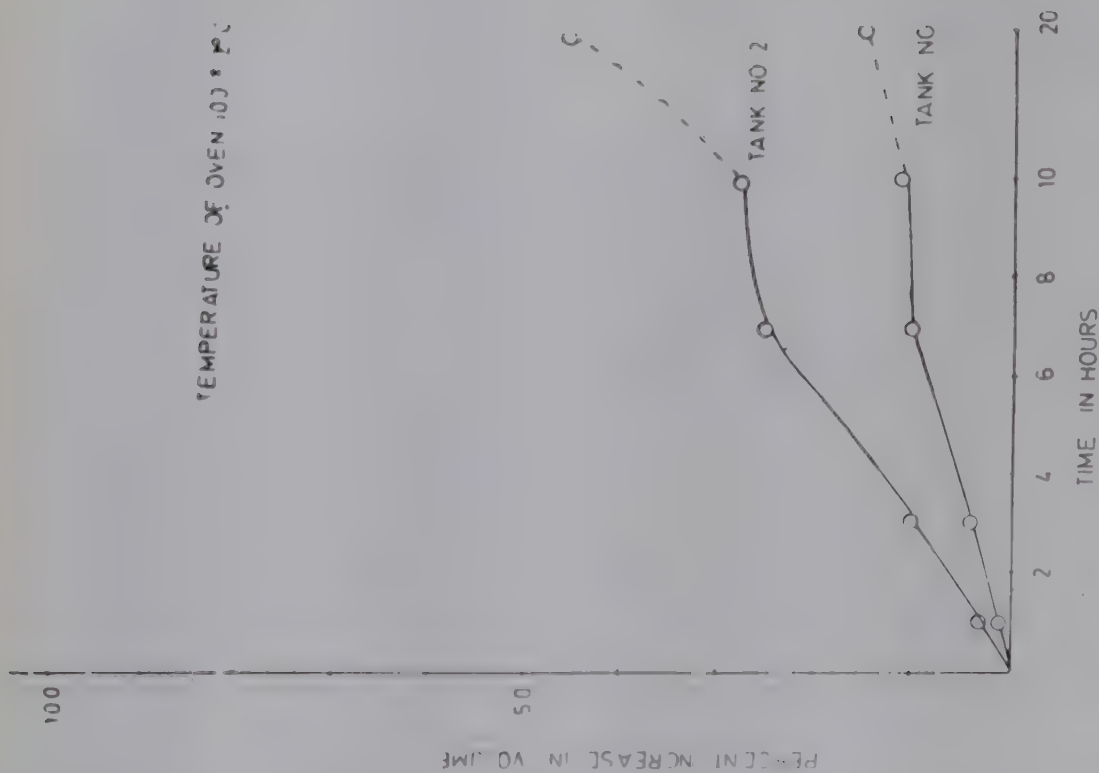


FIG 5 BEHAVIOR OF THE SAME MOLASSES AFTER INHIBITION OF THE PHENOMENON ON HEATING IN OVEN PURITIES

TEMPERATURE OF OVEN 100 ± 2°C

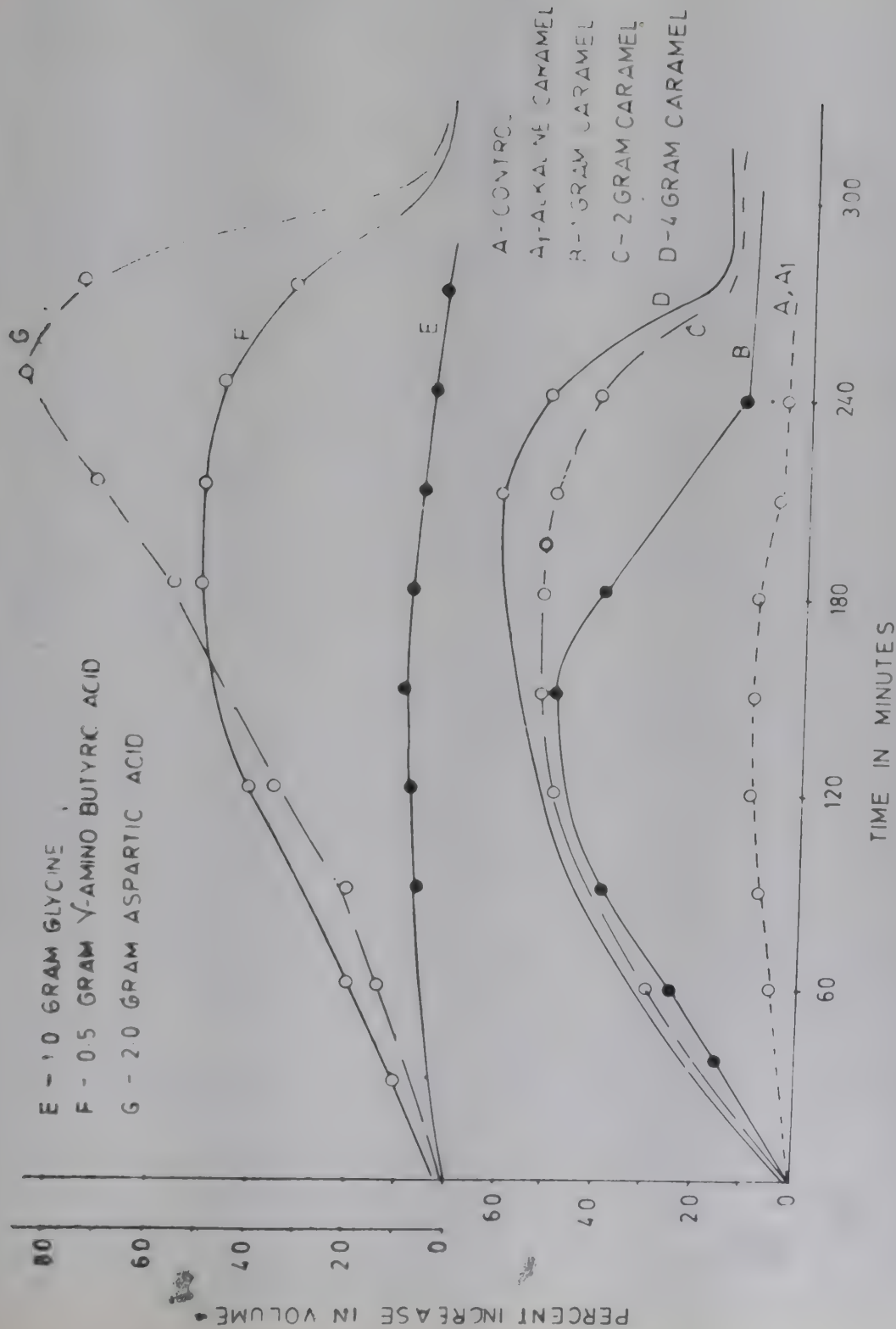


FIG 6 BEHAVIOR OF MOLASSES ON HEATING WITH EXTRENEOUS ADDITION OF VARIOUS TYPES OF CARAMELS AND AMINO ACIDS

A NEW JUICE CLARIFIER IS BORN

By

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ABSTRACT

A new design of Juice Clarifier is described and compared with other clarifiers. It is calculated that the new juice clarifier gives a gain in sugar recovery by reducing the inversion losses by reducing time of juice retention.

Introduction

The treated juice, whether by sulphitation, defection or carbonation, needs to be settled in order to separate the sediments from the clear juice formed as the result of the chemical treatment. The settling of juice is now done in continuous settlers, commonly known as 'Clarifiers'. Earlier, the settling was carried in rectangular ordinary tanks which used to work batchwise.

The most commonly used Clarifier is the 'Rapi-Dorr'. This clarifier consists of 4 compartments having a fixed total 'depth' of 20'. The recommended capacity of the 'Rapi Dorr' clarifier is at the rate of 125 cu.ft./t.c.h. which suggests a retention time of about 4 hours.

The settling tanks had a combined capacity at the rate of 60—65 cu.ft./t.c.h. Thus the

detention time in the settling tanks was not more than 2 hours i. e. about half that of the 'Rapi-Dorr' Clarifier.

Sugar Losses :

Since the losses of sugar by inversion under similar conditions of pH and temperature are proportional to time, the losses of sugar in the 'Rapi-Dorr' clarifier may be estimated as twice that of in settling tanks. Honing (Proc. 9th Congress I.S.S.C.T. 1956 PP. 550) estimates inversion losses in clarifier, in spite of all the precautions of pH and temperature to be 0.2 or 0.3% and these can increase sometimes to 1%. In sulphitation sugar mills, the normal purity rise from mixed juice to clarified juice should be 0.8 to 1.5. But of late, the trend is that either the purity gain is insignificant or there is a purity fall. This suggests a very

marked deterioration of juice in the clarifiers. It is also evident from the following tables.

Purity of M. J.	Purity of treated juice at inlet point of	Purity of clarifier juice from O. F. Box of clarifier (Rapi-Dorr)
82.43	84.10	82.68

(The above figures are average of 5 readings)

The above suggests that purity loss in the clarifier is of the order of 1.42 units.

Thus the continuous clarifier can be said to have the following comparison with the settling tank.

1. Loss of sugar is considerably higher.
2. The floor area required is less.
3. The human factor from settling operation is largely eliminated.

Scope for improvement in the design of Clarifiers :

We have already seen that the settling tanks worked at 2 hours maximum retention time. Also it is a common knowledge that in cylinder laboratory test, the settling to 20-25% volume takes not more than 40 mins. Hence a clarifier can be developed which should not detain juice for more than 2 hours.

The New Clarifier is born :

Keeping the above scope in mind, the author experimented for several years and ultimately found Clarifier which as actually worked at less than 2 hours holding capacity.

The Sketch shows the details of the Clarifier design.

The Flash Tank :

The Flash Tank serves dual purpose-one to eliminate all the 'flash' from the juice and also to flocculate the precipitate. This flash tank can be provided with any clarifier and it is found that it increases the settling capacity of the clarifier by about 10-15%.

The Feed :

The Clarifier is fed with juice entering at a velocity of 100/120 ft./hour to ensure extra gain in flocculation.

The Juice withdrawal :

From the upper compartment, the clarifier juice is withdrawn from a peripheral gutter and from the bottom compartment, it is withdrawn from a pipe concentric to the feed pipe.

Working Results :

A 100 T.C.D. Clarifier was built and installed at the sulphitation Khandsari Sugar Mills of Messrs Bhawanthadi Khandsari Sugar Mill, Village Bamhani, Distt Balaghat (M.P.). The crushing capacity of the factory is 100 T.C.D. per 20 hours working.

The size of the clarifier is as follows :

Dia.	—	—	6' 6'
Working height	—	—	10'
Working volume	—	—	340 cu. ft.

The clarifier was run upto the overflow level of the bottom compartment i. e. it was filled to a volume of 235 cu. etc.

Avg. crushidg rate obtained	—	—	4.61 tons
Juice percentage on cane	—	—	69.5
Juice obtained/Hrs.	—	—	3.204 tons
Volume of Juice/Hr.	—	—	103 cu. ft.
Retention time	—	—	2 hrs. 17 mts.
Bx. of raw juice	—	—	19.80
Purity of juice at clarifier	—	—	80.51
Purity of juice at clarifier inlet	—	—	82.30
Purity of clarified juice	—	—	82.00
Loss of Purity	—	—	00.30
Purity rise	—	—	1.49

Discussion :

The New Clarifier has worked on 2 hours 17 mts. retention time giving 1.5 purity rise for the juice of 19.8 Bx. The Bx. of raw juice in Sugar Mills is 15-15.5. Hence the time of

settling in Sugar Mills may be expected considerably less than 2 hours 17 mts. According to Hugot (p.434) 2% longer time is required for settling per degree Bx. rise over and above Clarifier in Sugar Mills should be about 2 hrs. 05 mts. With better control of condition of

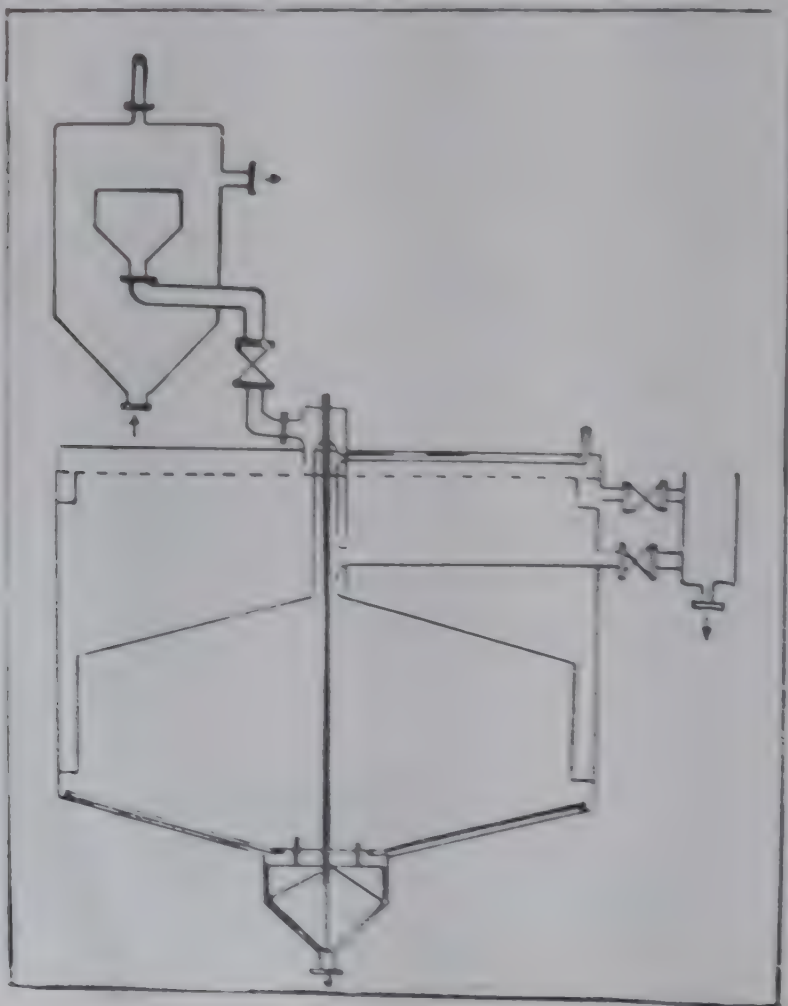
pH, temperature etc. than the Khandsari Sugar Mills, the Sugar Mills Clarifier should work at less than 2 hours retention time.

Conclusion :

The new Juice Clarifier promises great improvement in clarification technology. The time of retention is slashed by about 50%. Consequently extra gain in the purity of clarified juice may be expected to be 0.5 to 1 unit

which corresponds to 0.06 to 0.12% gain in sugar recovery.

The gain is by no means negligible, A Sugar Mill of 1250 tons cane/day capacity stands to gain 1620 Qls. of sugar in 5 months season at an average gain of purity of clarified juice of 0.75. This is likely to change the economic position of marginal Sugar Mills from red to green.



A CRITICAL STUDY OF THE CAUSES FOR HIGH MUD VOLUME FORMATION IN SULPHITATION SUGAR FACTORIES IN INDIA

By

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ABSTRACT

It is generally observed that sulphitation sugar factories in India experience the problem of high mud volume in clarification during the running of the factories. The problem was studied on a factory scale in two sugar factories; one in Maharashtra and the other in Tamil Nadu. In the present paper an attempt has been made to analyse the various reasons for the high mud volume and the remedial measures to be taken for solving the problems.

Introduction

Most of the Sugar factories producing white plantation sugar for direct consumption by the double sulphitation process experience the the problem of high mud volume during certain periods of the running season. The high mud volume generally disturbs the smooth working of the factory and also reduce the crushing capacity to a large extent. In order to study the problem and the reasons that lead to high mud volume, two sugar factories, one in Maharashtra and the other in Tamil Nadu were selected for studying the causes.

and high mud volume are cane variety, cane quality including stale cane, composition of juice, density of juice, defective clarification, sub standard chemicals used, nature and design of equipments used, working of clarifier, and working of filtering units etc. Poor cane quality i.e. cane with tops, roots, green leaves, trash, water shoots¹, off shoots, clay and soil particles and stale cane etc. is also responsible for mud troubles. Green tops, off shoots and buds of cane contain phenolic matter. Tannin is one of these constituents and hinders filtration. Stale cane due to highly viscous juices creates settling difficulties. With staling it has been observed that the phosphate content in the juices also goes down. Soils passing to

The factors responsible for settling trouble

the process from canes harvested from wet fields increase the amount of mud.

The cane juices which have high silica but low phosphate content in general are said to be refractory juice. Refractory juices result in high mud volume. Schmidt says that coagulation of small particles forming large flocs is hindered in case of refractory juices.

The nature of the non-sugars that are present in the mixed juice are greatly responsible for the behaviour of juice during clarification. It was pointed out earlier³ that chief constituents responsible for high mud volume are generally tannins, higher phosphate content.

Once the mud trouble is set in and if sufficient steps are not taken for its control the mud volume goes on increasing. The mud being thin adversely effects the filtration efficiency of the oliver vacuum filter. There is increase in recirculation of the solids to the sulphiters/clarifiers and ultimately the crushing has to be reduced.

Some of the points which should be taken into account and which would be helpful in reducing the mud problem are given below :

1. For removing major portion of sand and soil from the juice is to be done. The Dorr Clone has given satisfactory results.

Those factories which are not provided with sand soil separating device should liquidate the clarifier and clean it periodically.

2. The bagacillo content of screend⁴ juice should not be more than .7 gram/liter as it

would adversely effect clarification. Vibrating screens of at least 15×15 perforations per sq. inch and preferably 20×20 perforations per sq. inch should be used for removing crush from the mixed juice.

3. The intermixing of the treated juice and the raw juice due to leakage of a valve etc., is to be avoided.

4. Viscosity of juice increases with its density (or the brix) under the same conditions of temperature and pressure, the settling rate is faster at lower brix of juice. Juice of 15-16 Brix is considered to be good for satisfactory clarification. The brix of the juice obtained in the factory is dependent on maceration and the limiting factors are the evaporator capacity and the capacity of the clarifiers. As by abnormally increasing the juice quantity (by increasing maceration or by adding water to weighed mixed juice) the velocity of the juice in the clarifier may increase and hinder settling and the advantage of lower density of juice be off set by this. Therefore, a compromise should be made to balance the maceration rate.

5. Intermixing of the treated and raw juice should be avoided which may take place due to leakage of valves.

6. The temperature of the treated juice should be kept 100°C and preferably 102°C - 105°C but in this case the capacity of the flash tank should be sufficient to deal with the extra flash other wise some vapours if they go to the clarifiers will adversely affect settlings. The temperature of the raw juice may be raised to 75° - 80°C .

7. A uniform pH should be maintained. The settling rates are faster with slightly alkaline limed and sulphited juices and the mud volume is also less and more compact mud are obtained. The clear juice be kept at 7.0 to 7.1 pH.

8. The pumping of limed and sulphited juice to the clarifier should be at a uniform and regular rate as far as possible.

9. In acute mud troubles the pH of muddy juice be kept to about 7.6 as alkaline muds filter more easily. The filtrates out of this muddy juice when mixed with the raw juice will partly work as a preliming.

10. The P_2O_5 content of the mixed juice be kept at 300-350 mg/litre to obtain better clarification and settling. If the juice is deficient in phosphate content it should be made up by adding in the form of Triple Super phosphate, single super phosphate, di-calcium phosphate.

11. The quality of lime and its preparation before adding to the mixed juice plays an important role in settling and mud volume. The quality of lime stone used should be good. A magnesium content of above 2% in lime stone will result in high mud volume.

12. Milk of lime of 10%Be-12%Be gives very good settling results. A classifier may be used so that there is not much grit going to the milk of lime. A vibrating lime grit classifier with 80 mesh per sq. inch screen to remove the lime grit continuously or a korom classifier be installed.

13. Good quality sulphur and sufficient

quantity of air for complete combustion are necessary for good clarification.

14. It is necessary to find out the optimum dose of lime. The clarity of clear juice, the rate of setting and the mud volume will depend upon the initial composition of the juice, and the treatment given in clarification so that best results may be obtained under these conditions.

15. Flocculating agents are used as settling aids to improve floc formation. These are poly electrolytes, synthetic poly electrolytes of higher molecular substances. By the bridging action of the flocs already formed, the settling rate is increased, optimum dose of these flocculants which are effective are first determined.

Experimental

Work done at M/s. Vasant Sahakari Sakhar Karkhana Ltd., Vasantnagar, District Yeotmal Maharashtra State.

Sugarcane is this factory is received at the factory gate by means of carts and trucks and there is no road purchasing centre. The cane which was being received at the time of the study was Co 740 variety 80%, Co 429, 15%, included Co 62175.

The factory was having equipments as laid down in standard specifications for 1250 TCD. The working conditions prevailing in the factory at the time of the study are summarised below :

(a) The P_2O_5 content in the mixed juice was more than 500 mg per litre.

of the clear juice was 7.0-8.10 and the mud in the rapidorr clarifier was 8 and 8 cocks. The sulphited juice was made on the slightly alkaline side so that the pH of the clear juice was 7.2 and the mud level in the upper one fell to 7 cock and in the lower one to 6 cock only. There was break down at the Boiler on 25.3.78 as one of the tubes of the super heater at one Boiler leaked. The factory closed down crushing on 25.3.78 for cleaning. The factory resumed crushing only on 27.3.1978 with one boiler and with reduced crushing rate. During the shut down the Rapidorr was also liquidated. After the resumption of crushing on 27.2.78, the pre-liming of the raw juice was also done and the optimum dose of milk of lime was used during the clarification. The mud level in the rapidorr remained only at 1 cocks.

2. Work done at M/s. Dharmapuri District Cooperative Sugar Mills Limited Palacode (Tamil Nadu)

The Dharmapuri District Cooperative Sugar Mills Limited, Palacode is crushing at the rate of about 1400 Tonnes of Sugar cane per day.

The cane in this factory is received by carts and trucks. Co 419 is the main variety of cane besides the balance consisting of Co 658, Co 853, Co 62198, Co 6304, Co 6806, Co 62175.

The factory is provided with plant and machinery required for 1250 TCD as per standard specifications.

Simultaneous liming and sulphitation was followed by the factory. Of course, a little

pre sulphitation was done by the stock gasses going out to the juice incoming in the continuous juice sulphitation vessel (N S.I. design).

Experiments and investigations are as follows :—

Factory at that time was using milk of lime 2.3% by volume of juice and the Brix of lime was 10.

Experiment conducted :

The following experiments were conducted.

Experiment No. 1 :

500 ml of juice was taken at three places. Each of these was first heated to 70°C and then limed and sulphited using milk of lime 2.3%, 2.6% and 3% of 10 Brix. Each one of these were first heated to boiling and then transferred to three graduated glass cylinders which were made thrice upside down and the settling rates noted. It was found that minimum mud volume of 21.2% was obtained when milk of lime 3% by volume of 10 Brix was used. Also the CaO content was lowest and was 1470 mg/litre and 9131 mg/litre/100 Brix. The results are given in table-IV.

Experiment No. 2 :

500 ml of raw juice was taken at three places. One portion was heated to 70°C and then limed and sulphited using milk of lime 3% by volume of 10° Brix.

Another portion of 500 ml juice was heated to 70°C and then presulphated to 5.15 pH and then limed and sulphited using milk of lime 3% by volume of 10° Brix.

Another portion of 500 ml 500 ml raw juice was prelimed to 6.7 pH and then heated to 70°C and limed and sulphited using milk of lime 3% by volume of 10° Brix.

All the three 500 ml graduated glass cylinders which were made upside down thrice and then kept vertical. The mud volume was least in case of preliming and the purity rise was also more being 1.07. The results are mentioned in table V.

Experiment No. 3 :

500 ml of raw juice (P_2O_5 content 305 mg/litre) were taken at three places for the purpose. It was found that the mud volume was least in case of preliming method and the purity rise was also more as compared to the other two methods being 1.33. The CaO content was also less in the case of the preliming method being 10680 mg/litres/100 Brix as compared to other two methods. The results are mentioned in table 6.

The CaO content, reducing sugars, Phosphate, Tannis, Ash, Organic nonsugars of raw juice as determined during the visit given in table 7.

The active CaO in lime which was being used by the factory was found as 51.6.

It was found that the rotation of the drum of the Eimco-K. C. P. Vacuum filter was one rotation per 4.25 minutes. Quantity of Bagacillo which was being added to the muddy juice was determined as 11.11 lbs. of Baga-

cillo per ton of cane. Screening area for the Bagacillo was 58.33 Sq. feet and the sieve used was having 18 holes per sq. inch, diameter of the holes being 3 mm.

The stirrer of the correction tank of the continuous liming and sulphitation tank was not working.

Observations made

Based on the above laboratory experiments the pre-liming alongwith addition of phosphate to the mixed juice wastried in the factory. However, it may be mentioned that the clarifier had four mud cocks. The third mud cock was jammed & the fourth mud cock was plugged and as such mud level upto two cocks could be seen.

During the period of observation in the factory phosphate was added to the mixed juice to make up its P_2O_5 content to 300-350 mg/litre. Preliming was done to 6.3-6.7 pH raw juice tank in which weighed raw juice was being dropped. The raw juice was heated to 70°C, liming and sulphitation done in the continuous juice sulphitators. The milk of lime used during the period was 3% by volume of 10° Brix. The mud level which was above 2 cocks (as cock No. 3 and 4 were jammed and mud level in these could not be observed) came down so much so that the second cock became clear. The clarity of the juice also increased very much during the above pretreatment. The analysis of mixed juice and clear juice as recorded by the factory during the period is as follows :

Mixed Juice

Brix	Pol	Purity
15.08	12.12	80.37

Clear Juice

Brix	Pol	Purity
15.52	12.49	80.48

It may be mentioned here that the factory had been using sedipur at the rate of 2 ppm as a settling aid. This was stopped during the period, the observations were made in the factory and even then the mud level went down with the above mentioned pre treatment.

Conclusion*Vasant Nagar Sugar Factory*

It was found in the laboratory experiments that where factories crushed cane of predominantly Co. 740 variety the preliming of cane juice to 6.8 pH gave the least mud volume as well as higher purity rise as compared to the simultaneous liming and sulphitation and pre-sulphitation.

Palacode Sugar Factory

It was found that preliming of the raw juice to 6.7 pH and then heating to 75°C where cane crushed was of predominantly Co

419 variety gave lesser mud volume as compared to the other method i. e. simultaneous liming and sulphitation method and the pre-sulphitation method. The same adopted in the factory also resulted in reducing the mud level in the clarifier.

Factories crushing predominantly Co 419 variety often may adopt the pre-liming of the juice and then heating to 95°C and liming and sulphiting when ever they are confronted by severe mud problem.

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Table—1.**Determination of Optimum dose of Milk of lime**

Heated the juice to 75°C and then limed and sulphited using varying doses of milk of lime 3.5% by volume, 4.0% by volume, 4.5% by Volume.

Brix % 17.79, Pol % 14.60, Purity 82.08.

Time in minutes	Using 3.5% milk of lime of 7.5° Be	Using 4.0% milk of lime of 7.5° Be	Using 4.5% milk of lime of 7.5° Be
0	515 ml	515 ml	515 ml
5	360 ml	395 ml	360 ml
10	250 ml	288 ml	250 ml
15	215 ml	242 ml	207 ml
20	195 ml	222 ml	187 ml
25	180 ml	202 ml	174 ml
30	175 ml	195 ml	165 ml
60	145 ml	162 ml	138 ml
Mud Voiume per cent	28.16	31.46	26.80
Brix	17.82	17.84	17.7
Pol	14.70	14.80	14.70
Purity	82.49	82.96	83.05

Table-2

Heated the juice to 75°C and then limed and sulphited using milk of lime 4.25% by volume of 7.5° Be.

Heated the juice to 75°C, then presulphited to 5.2 pH and then limed and sulphited using milk of lime 4.25% by volume of 7.5° Be.

Pre limed the juice to 6.8 pH and then limed and sulphited using milk of lime 4.25% by volume of 7.5° Be.

Raw Juice Brix 15.02, Pol 12.39 Purity 82.49.

Time in minutes	Simultaneous liming and sulphitation	Pre-sulphitation	Pre-liming
0	500 ml	500 ml	500 ml
5	260 ml	245 ml	230 ml
10	195 ml	180 ml	160 ml
15	170 ml	155 ml	138 ml
20	152 ml	138 ml	123 ml
25	140 ml	128 ml	113 ml
30	135 ml	122 ml	107 ml
60	112 ml	107 ml	95 ml
Mud volume per cent	22.40	21.4	19.0
Brix	15.14	14.99	15.14
Pol %	12.58	12.58	12.73
Purity	83.09	83.92	84.08
Purity rise	.60	1.43	1.59
CaO mg/litre per 100 Brix	5483	5537	5515

Table-3

Analysis of Mixed Juice for various constituents

Brix	Pol	Purity	CaO mg per 100 Brix	Reducing Sugar per 100 Brix	Gums per 100 Brix	P ₂ O ₅ per 100 Brix	Tanins per 100 Brix	Ash per 100 Brix	Organic non sugar per 100 Brix
18.02	15.13	83.96	7712	10.56	2.87	.1337	.14	3.36	12.6743
15.02	12.39	82.49							

Table-4

Determination of optimum lime dose.

Three Sets of 500 ml raw juice were heated to 70°C and them limed and sulphited using 2.3%, 2.6% and 3% of milk of lime of 10° Brix. Each of these were heated to boiling and then transferred to glass cylinders and made upside down thrice and then allowed to settle.

Raw Juice : Brix 15.83 Pol % 12.06, Purity 76.17

Time in minutes	Simultaneous liming and sulphitation using 2.3% milk of lime of 10° Brix.	Simultaneous liming and sulphitation using 2.6% milk of lime of 10° Brix.	Simultaneous liming and sulphitation using 3% milk of lime of 10° Brix.
0	500 ml	500 ml	500 ml
5	485 ml	440 ml	425 ml
10	475 ml	375 ml	225 ml
15	460 ml	215 ml	175 ml
20	415 ml	185 ml	155 ml
25	250 ml	165 ml	140 ml
30	155 ml	145 ml	135 ml
35	145 ml	140 ml	130 ml
60	115 ml	115 ml	106 ml
Mud volume percent	23.0	23.0	21.2
Brix	16.12	16.30	16.10
Pol %	12.39	12.53	12.42
Purity	76.86	76.87	77.14
Purity rise	.69	.70	.97
CaO mg/Litre	1520	1580	1470
CaO mg/litre/100 Bx.	9428	9694	9131

Table—5.

- a) 500 ml of raw juice heated to 70°C and then limed and sulphited using milk of lime 3% by volume of 10 Brix.
- b) 500 ml of raw juice heated to 70°C and then pre sulphited to 5.15 pH and then limed and sulphited using milk of lime 3% by volume of 10° Brix.
- c) 500 ml of raw juice pre limed to 6.7 pH and then heated to 70°C and limed and sulphited using milk of lime 3% by volume of 10° Brix.
- d) All the three were heated to boiling separately and then transferred to three 500 ml glass cylinders which were made upside down thrice and then kept for settling.

Raw juice Brix 14.42 Pol % 11.08, Purity 76.84

Time in minutes	Simultaneous liming and sulphitation	Pre Sulphitation	Pre-liming
0	500 ml	500 ml	500 ml
5	485 ml	425 ml	425 ml
10	425 ml	335 ml	385 ml
15	315 ml	245 ml	270 ml
20	240 ml	215 ml	215 ml
25	207 ml	185 ml	185 ml
30	195 ml	180 ml	175 ml
60	140 ml	135 ml	130 ml
mud volume per cent	28.0	27.0	26.0
Brix	14.4	14.58	14.58
Pol	11.18	11.33	11.36
Purity	77.64	77.71	77.91
pH	7.0	6.9	6.95

Table 6

- (a) 500 ml of raw juice was heated to 70°C and then limed and sulphited using milk of lime 3% by volume of 10° Brix.
- (b) 500 ml of raw juice was heated to 70°C and then presulphited to 5 pH and then limed and sulphited using milk of lime 3% by volume of 10° Brix.
- (c) 500 ml of raw juice was prelimed to 6.6 pH and then heated to 70°C and limed and sulphited using milk of lime 3% by volume of 10° Brix.

Analysis of Raw Juice: Brix 14, Pol % 11.36. Purity 81.19, pH 5.3 P_2O_5 305 mg/litre

Time in minutes	Simultaneous liming and sulphitation	Pre Sulphitation	Pre liming
0	500 ml	500 ml	500 ml
5	475 ml	375 ml	475 ml
10	210 ml	245 ml	175 ml
15	175 ml	185 ml	150 ml
20	150 ml	160 ml	135 ml
25	140 ml	150 ml	125 ml
30	135 ml	140 ml	118 ml
65	106 ml	110 ml	94 ml
Mud Volume per cent	21.2	22.0	18.8
Brix	13.99	13.98	14.15
Pol %	11.45	11.47	11.67
Purity	81.84	82.05	82.47
Purity rise	.70	.9	1.33
CaO mg/litre	1580	1700	1510
CaO mg/litre/100 Brix	11290	12160	10680

Table 7

Composition of Cane Juice

Brix	Pol	Purity	CaO mg/litre per 100 Brix	Reducing Sugar per 100 Brix Brix	Phosphate per 100	Tanins per 100	Ash per 100 Brix	Organic Non Sugar per 100 Brix
14.0	11.36	81.14	5041	9.13	.107	.106	3.459	11.54
14.42	11.08	76.84						
15.83	12.06	76.17						

CHEMICAL COMPOSITION AND CLARIFICATION CHARACTERISTICS OF JUICES AS AFFECTED BY LODGING OF SUGARCANE

By

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ABSTRACT

Efforts have been made in the present study to observe consequences on lodging of certain technological aspects. As a result of lodging of cane it has been found that diverse type of changes in the juice composition, such as increase in phenol, amino acid and potassium contents and decrease in total & available P_2O_5 content occurred. In concurrence with chemical composition data the clarification and settling characteristics along with various other parameters revealed inferiority of juices of lodged canes as compared to juices of unlodged cane. Steps necessary for improving the clarification of lodged cane juices are also indicated.

Introduction :

Cane being raw material for sugar industry, complex and multiple type of factors which effect its (sugarcane) quality have a direct bearing on the manufacture of cane sugar. While the tonnage is matter of concern to the grower, chemical composition of juice is of importance to the processing technologist. Although, sucrose is prime measure of quality, wide variety of compounds that occur in cane juices are also known(5) to play a vital role in processing of cane juice. For example-crushing phosphate

deficient and post harvest deteriorated canes are found to create difficulties during clarification. Lodging of sugarcane is perhaps one such phenomena which exerts influence on both yield and quality of cane. According to Burton(1) due to lodging, sugarcane loses as much as 25% of sugar. It was observed that lodged cane accumulates more starch in relation to erect ones(7). However, very little is known regarding other organic and inorganic constituents of juices that are affected by lodging. Similarly, from the literature it is obvious

that the after-effects of lodging on clarification of cane-juice have not been studied. A preliminary study has, therefore, been taken up to investigate the consequences of lodging on composition and effects on clarification of such juices.

Methods and Material :

In an effort to study the influence of lodging on composition of juice, different constituents have been estimated in lodged cane stalks of variety Bo-34. Total polyphenols (TPP) and total amino acids have been determined spectrophotometrically in accordance with methods described by Swain and Hillis (11) and Williams and Wiggins (12). Total nitrogen, phosphorous and potassium were estimated after wet digestion of juice by procedures described elsewhere (6). CaO content, available P_2O_5 and reducing sugars have been analysed directly from raw juices using standard methods of analyses. In order to study clarification aspect at laboratory scale, clarification of juices has been done and details of the schemes are mentioned later. All the observations were carried out from naturally lodged cane and compared with that of erect canes of the same variety from the same plot.

Results and Discussion :

Influence of lodging on composition of juice :

Several features were brought into light regarding chemical composition of lodged as well as unlodged cane juices during the present study. Results of these analyses are summarised in Table 1. To avoid brix discrepancy, the results are calculated for 100° Bx. Overall total polyphenols, total amino acids and fibre % cane were found to be

higher in lodged canes as compared to unlodged canes. In contrast to this, total and available P_2O_5 and K_2O contents were higher in erect canes. Total Nitrogen and GaO content did not show much variations.

There was about 17.41% increase in total phenolic content in juice of cane stalks which suffered 90° inclination. The phenols are known to induce enzymatic and non-enzymatic colour formation in cane juices (3, 4). Therefore, their presence in cane juices in more quantities is not a good indication. Although no efforts have been made to evaluate whether this increase is due to exogenous phenols or indogenous phenols, it is conceivable that high anthocyanin production in cane rinds might be the reason for more TPP content in juice. This is because, due to lodging, unit area per stalk to sun-light exposure increases and photoinduced anthocyanin production is not uncommon in many plants (8). Incidentally authors have observed this situation to occur in sugarcane as well (9).

Very little variation was observed between total Nitrogen content of both type of samples, but total amino acid content was 9.82% more in lodged canes. Accumulation of more amino acid while on one hand reflects the growth condition of cane, on the other, it opens possibility of higher production of melanoidin colorants during clarification and processing of the raw juices. Adverse effects of increased amino acid contents on exhaustibility of final molasses are also well known.

Significant behaviour in respect of

phosphates was observed. Owing to the role in root development of cane, phosphate deficiency is known to promote lodging habit of cane(7). In the present case total phosphate content in juices of lodged cane was found to be 15.68% more than that of the controls, i. e. unlodged cane. But, with the results at hand, it is difficult to conclude whether phosphate deficiency induced lodging or lodging itself curtailed accumulation of phosphate. Somehow lodging indicates to have exhibited a close relationship with phosphates. More interesting feature was of available or free phosphate content in juices of lodged cane which were 15.68% less over erect canes. In other sense, probably due to accessory growth activities, organic phosphate content was twice in lodged cane (303 mg/litre/100° Bx) in comparison to

straight canes (154 mg/litre/100° Bx). From manufacturing stand point it may be pointed out that only inorganic or available phosphate takes part in the clarification and, therefore, lodging apart from decreasing total phosphate (or Vice versa) converts much of the free phosphate into unavailable organic form.

Among all the constituents, per cent difference of potassium content was maximum between lodged and unlodged cane juice (18.20%). No appreciable change in CaO content was observed between two samples. The fibre % cane was, however, more in sample 2 (lodged canes) with respect to sample 1 (unlodged cane). Probably this might be due to increased vegetative growth in lodged canes.

Table-I
Chemical composition of cane juice as
affected by lodging

Constituents	Expressed as mg / litre / 100°Bx.		% decrease or increase in lodged
	Erect	lodged	
Total polyphenols	4039	4742	+ 17.41
Total amino acids	652	712	+ 9.82
Total nitrogen	5399	5363	— 0.60
Total phosphate	2294	2153	— 6.10
Available „	2140	1850	— 15.68

Contd.....

Constituents	Expressed as mg / litre / 100 ^o Bx.		% decrease or increase in lodged
	Erect	Lodged	
K ₂ O	6482	5484	— 18.20
CaO	4940	4979	+ 0.8
Fibre % cane	17.82	18.34	+ 3.0
Juice % cane	35	30	— 14.0

Each figure represents mean of 2 replicates

Effect of Lodging on Clarification of Juice

It has already been pointed out that lodging of sugarcane plant invariably affects the cane quality particularly in relation to the Bx. and purities of the raw juices (10). In this part, the response of raw juices, obtained from straight and lodged canes towards clarification is discussed. The raw juices as obtained from two types of canes crushed on power driven laboratory crusher were clarified using normal sulphitation process. To have a comparative study specially regarding settling characteristics, the two juices were made of approximately equal Bx(15.0). 1.5% milk of lime of 10^o Be was used for sulphitation. The juices after clarification were allowed to settle in a 250 ml. graduated cylinder and the settling rates, turbidity, haziness and scum were observed.

Fig. 1 indicates the settling rates of juices obtained in each case. It may be observed from the figures that 50% of the clear juice could be obtained in the laboratory experime-

nts within 13 minutes in case of lodged cane which could be done only in 9 minutes for juices of straight cane. The mud volume was also found to be much lesser in case of straight cane as can be seen by the graph. Moreover, slight haziness, turbidity and very small amounts of scums were observed in case of lodged cane which were not seen at all in the clarified juice obtained from the unlodged cane. The above facts indicated that the juices of straight cane showed better settling characteristics.

The optical density of clear juice at pH=7 was measured at 420 nm on Beckman spectrophotometer model B, in both the cases and it was observed that clear juice of lodged cane had more value (0.22) in comparison to unlodged one (0.135). This observation indicated the less removal and/or more of production of colouring matter from the juices of lodged cane, during its clarification, which was also supported by the results of amino acid content of lodged cane juice which appeared high and could produce more colorants by the reaction

of amino acids with the reducing sugars the extent of which was also found to be appreciably higher in lodged cane. It may thus be pointed out that owing to the formation of more colouring matter in lodged cane juice, the day-to-day working condition and the quality of the final products may be affected in factories where lodged cane in large proportion is processed.

The removal or addition of various constituents such as CaO , K_2O , P_2O_5 , reducing sugars and amino acids during clarification was found to be varying in the two juices (Table 2). Thus, the CaO addition observed was 50.66% and 55.4% for the straight and lodged juices respectively showing the greater entry of calcium in case of lodged cane during sulphitation, thereby increasing the non-sugar percentage to some extent. The elimination of potassium content during clarification was found to be 16.5 and 5.8% for straight and lodged juices respectively. The greater removal of K^+ during clarification in case of straight cane was in conformity with the greater purity rise observed (2). Further more, the greater removal of potassium during clarification of straight cane juice clearly indicated the possibilities of the presence of less non-sugars in various stages of processing there by making the molasses % low.

The removal of total amino acids was found to be higher (29.70%) in case of unlodged cane as compared to the lodged one (24.44%). Perhaps there might not be removal of amino acids but its utilization in the reaction with reducing sugars. This showed the possibilities of the production of more and more colorants by the maillard reaction at later stages of

cane juice clarification and processing of lodged cane juices.

The higher P_2O_5 content of cane juices in the unlodged canes might have been a favourable factor for better clarification and settling rates as compared to lodged cane where the P_2O_5 content was much lesser. While the actual practice, however, it is observed that residual P_2O_5 content in clear juice is independent of initial P_2O_5 content of raw juices, it was interesting to note that residual P_2O_5 content in clarified juices obtained as a result of clarification of lodged and unlodged canes had been found as 25 and 55 mg/l respectively. Reducing sugar % in lodged cane was found to be 3.34 as against 2.82 in unlodged cane, when evaluated on 100° Bx. With higher reducing sugar content there is a possibility, depending upon temperature and alkaline conditions, of the conversion into organic acids like aconitic, malic, glycollic succinic etc. The organic acids particularly aconitic and oxalic formed as a result of destruction of reducing sugars (the percentage of which was found to be slightly higher in case of lodged cane juices) react with calcium hydroxide to form salts creating difficulties of scale formation in evaporators. Since the solubilities of all these organic salts are sufficiently high, there are possibilities of these carried through the syrup and accumulate in the molasses during boiling, thus increasing the viscosity of the molasses and other massecuites.

From the above discussions it can be stated that juices of lodged cane show poor performance towards clarification particularly with reference to settling characteristics and

clarity of the clarified juices obtained. In order to improve the settling and clarification of the juices obtained from lodged canes, few experiments were laid down at laboratory by clarifying juice of lodged cane using few modifications. The clarification of such juices using different lime doses (1.5, 2 and 2.5%)

suggested that by increasing the lime dose to 2 and 2.5%, the clarification improved as can be seen from fig 2. The settling rates were found to be fast, volume of settlings less and optical density values low at increased lime doses as shown below :

Lime dose %	cc. Mud volume in 250ml.	Optical density
		at pH=7, mesured at 420 nm
1.5	96	0.12
2.0	84	0.085
2.5	75	0.080

The haziness and turbidity of clear juices obtained by employing increased lime doses could also improve appreciably. The juices of lodged cane were also clarified using pre-liming which gave encouraging results. The juices were found to have high settling rates (Fig. 3), low mud volume and absence of any

turbidity or haziness.

The above findings pointed out that using increased doses of lime and by employing pre-liming, the difficulties experienced in clarification on account of lodged cane could be considerably reduced.

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TABLE-2

Behaviour of Raw juices obtained from straight and lodged cane,
on clarification using normal sulphitation process

	Straight cane		% Increase or decrease from R J. to C.J.	Lodged cane		% Increase or decrease from R.J. to C.J.
	Raw juice	Clear juice		Raw juice	Clear juice	
1. Corr. Bx.	15.18	15.27	—	14.86	14.88	—
2. Pol %	12.43	12.53	—	11.72	11.72	—
3. Purity	81.89	82.12	—	78.91	78.78	—
4. Purity rise from raw juice to clear juice	+0.23			-0.13		
5. Reducing sugar % on 100 Bx.	2.82	2.72	-3.54	3.34	3.18	-4.79
6. CaO in mg/l	750	1130	+50.66	740	1150	+55.4
7. K ₂ O in mg/l	984	823	-16.5	815	768	-5.8
8. Available P ₂ O ₅ in mg/l	325	55	-83.08	275	25	-90.91
9. Amino Acids in mg/l on 100 Bx.	652	453	-29.76	712	538	-24.44
10. Optical density of clarified juice at pH 7 at 420 nm. Dilution 1:3	—	0.135	—	—	0.22	—
11. Final mud volume%—	—	30	—	—	40	—

SETTLING CHARACTERISTICS OF JUICES
OBTAINED FROM STRAIGHT AND LODGED
CANES (A typical set)

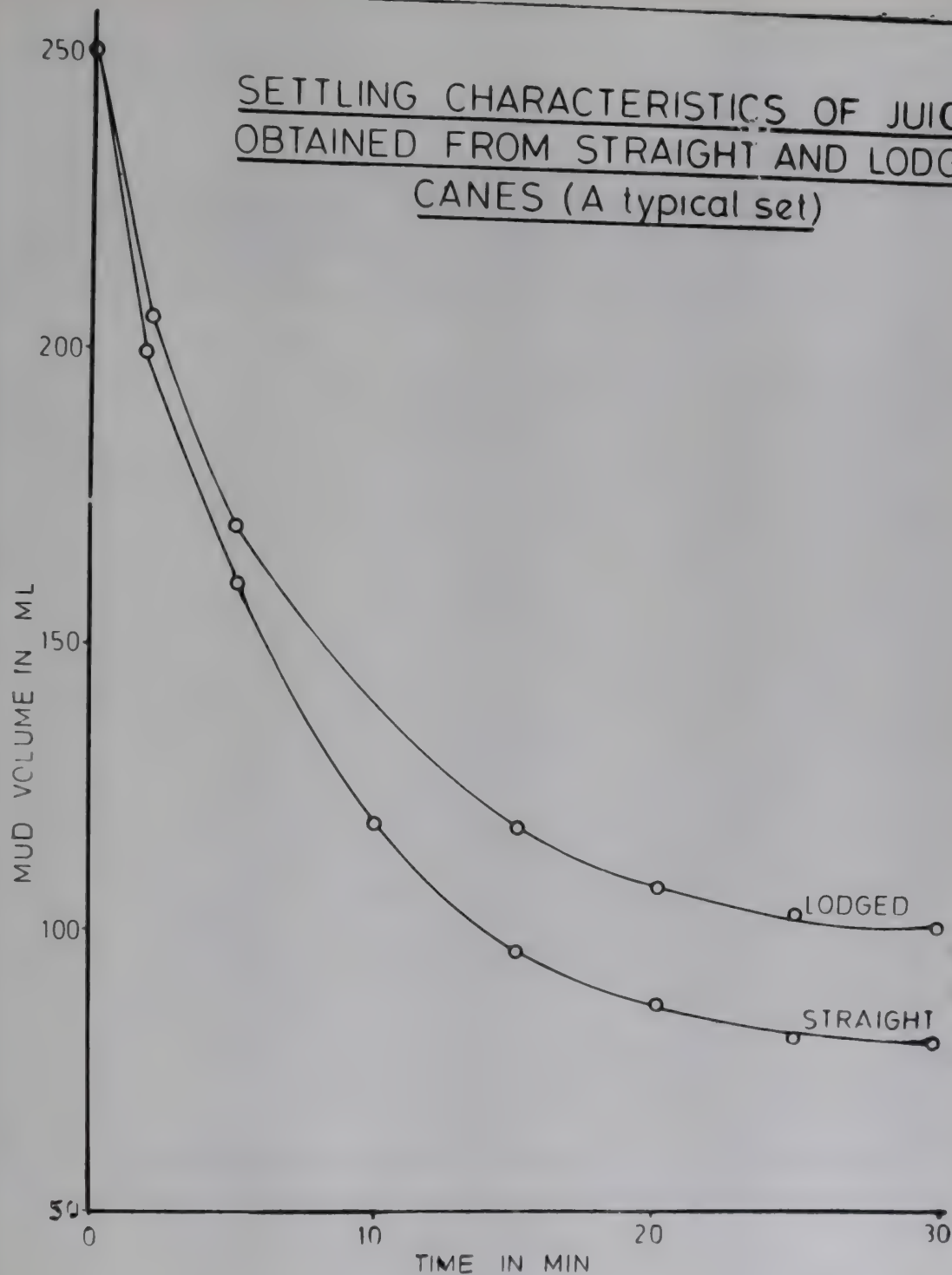


Fig. 1

SETTLING CHARACTERISTICS OF JUICES
OF LODGED CANE AT DIFFERENT DOSES
OF MILK OF LIME USED FOR SULPHITATION

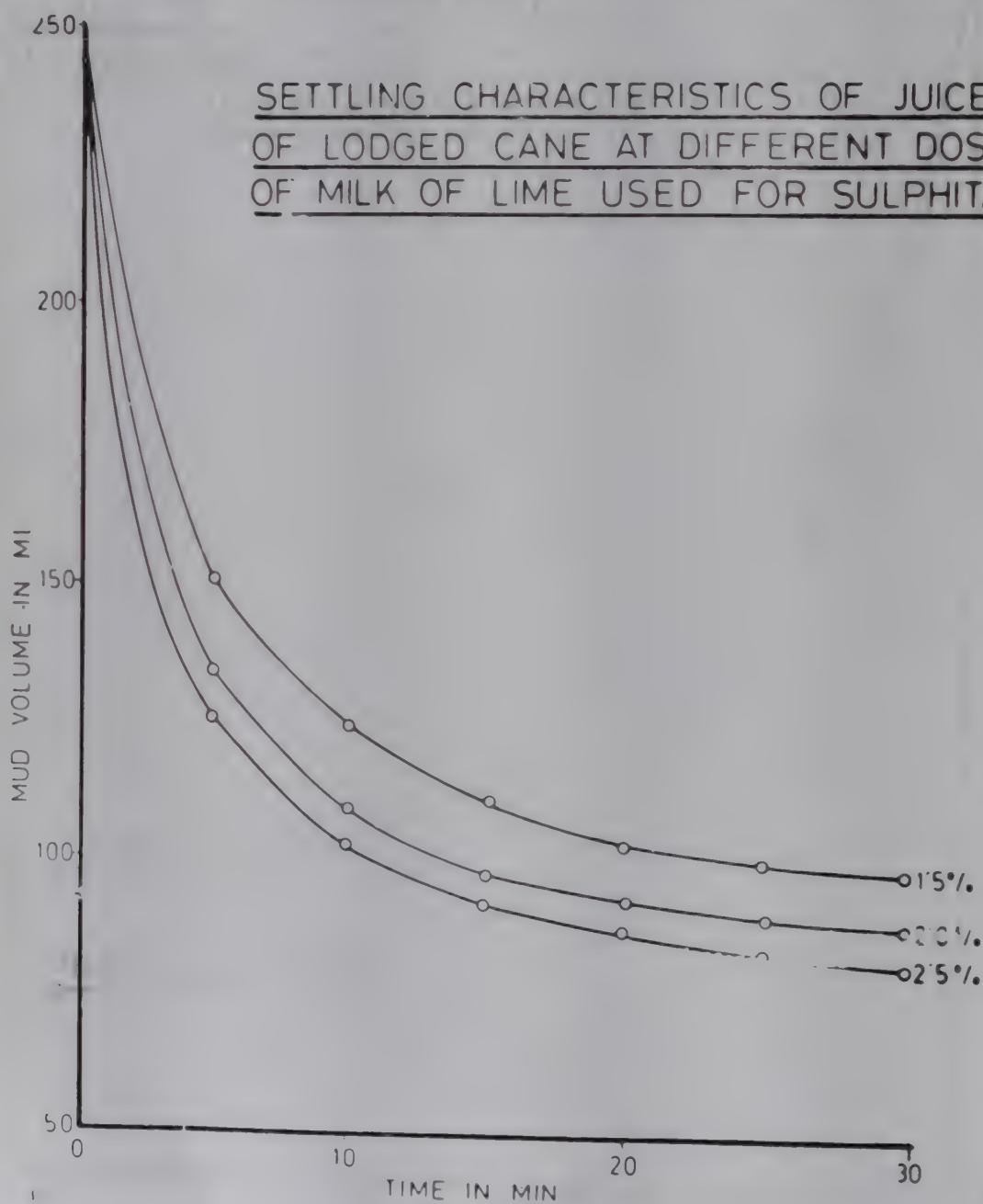


Fig. 2

INFLUENCE OF PRELIMING ON THE SETTLING
CHARACTERISTICS OF THE JUICES OF LODGED
CANE

1. NORMAL SULPHITATION WITH 2% LIME
2. PRELIMING WITH A TOTAL 2% LIME

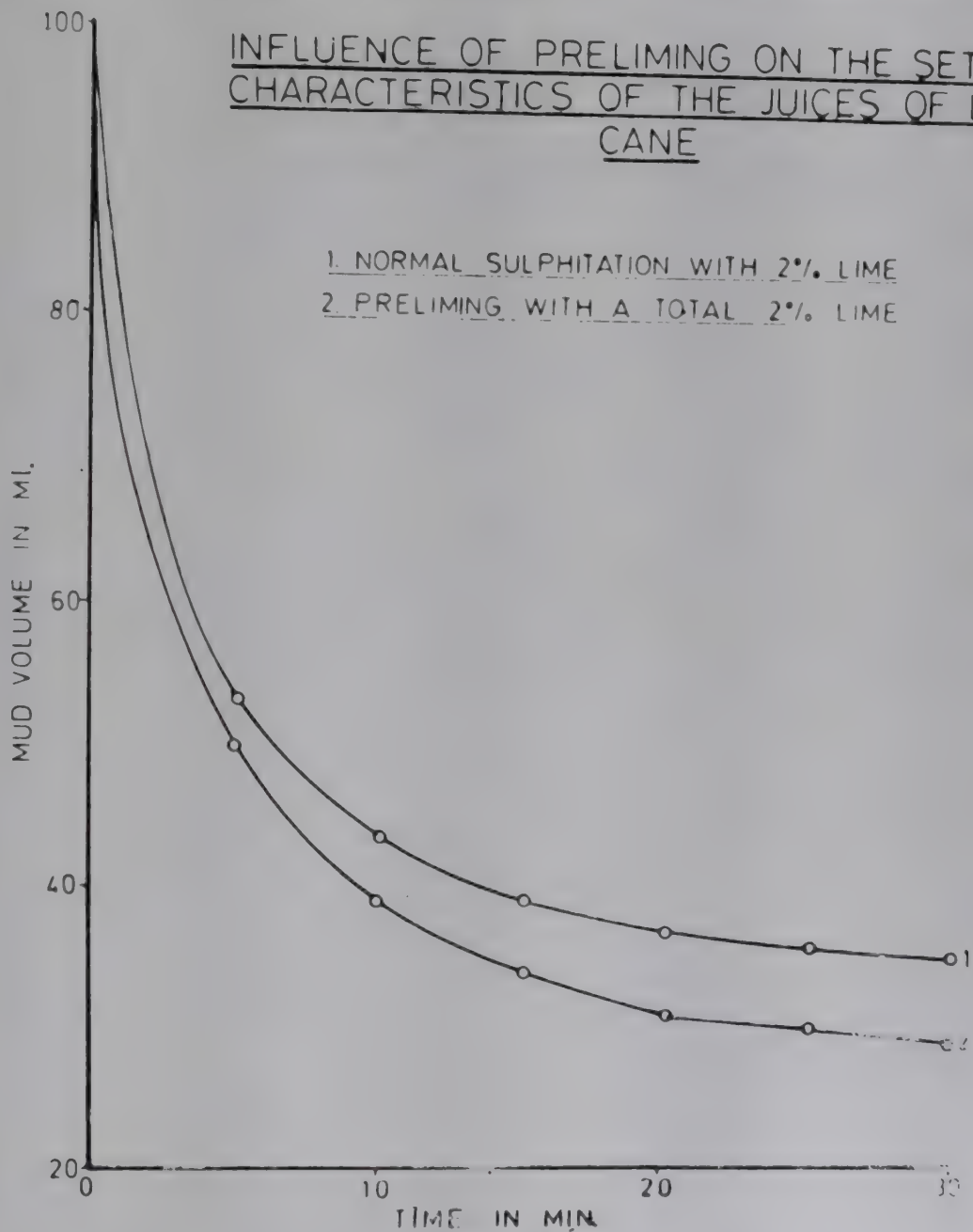


Fig. 3

NEW METHOD OF COMPOUND IMBIBITION PART I

By

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ABSTRACT

Adding maceration water over the crusher, after the shredder is recommended. Their modes of addition of maceration water are contemplated. It is mathematically proved by evolving a formula that there is increase in Primary Extraction by addition of maceration water over the crusher.

Introduction

In the process of compound imbibition as it is practised popularly in a sugar factory, water is added between the ultimate and penultimate mill, and admixture of juice and the water is circulated back on mills such that at every mill the bagasse receding from the previous mill meets with it, with the effect that we get maximum extraction on the mills.

Normally if we see, the prepared cane as it falls between the top and feed roller of the crusher, we find that this cut cane can be mixed with this admixture to get better

advantage of the crusher. The idea is to introduce juice and water on the cut cane before it enters the crusher. Mechanical arrangement can be very easily made and the purpose of this article is just to show mathematically the advantage of such system over the usual system of compound imbibition being followed in the factories.

The total water which is added on the mills i.e. added water % cane can be divided into two parts. Initially some water can be added on this cut cane following on the crusher and the remaining major portion of water can be added as usual in the process of compound imbibition.

In simple imbibition the 1st extraction is found out by the formula.

$$\frac{m - f}{m(1 - f)}$$

Where m = fibre per unit bagasse.

f = fiber per unit cane.

and 1 stand for unit juice.

According to the new system this formula will have to be revised as follows : —

Bagasse per unit cane = f / m

Now we have added W_1 to the cut cane at chute hence the term unit cane will have to be substituted by the term $1 + W_1$, Hence,

Primary juice extraction per unit cane

$$= 1 + W_1 - f / m$$

Now, cane = fibre + Juice.

$$\therefore \text{Juice} = \text{Cane} - \text{fibre} = 1 - f$$

While considering extraction of juice from the cane, cane will have to be treated as ' $1 + W_1$ ' instead of 1. Here W_1 will be the maceration water added on the cut cane at chute. Then the juice extracted from the cane will be $(1 + W_1) - \frac{f}{m}$. This juice is extracted from the juice $(1 - f)$ as explained earlier,

Therefore, for unit juice, extraction will be

$$\begin{aligned} & \frac{1 + W_1 - \frac{f}{m}}{1 - f} \\ &= \frac{m(1 + W_1) - f}{m(1 - f)} = \frac{m + mW_1 - f}{m(1 - f)} \quad (1) \end{aligned}$$

This is the formula for primary extraction.

Instead of adding pure water partially on the cane chute and then between ultimate and penultimate mills, this water can be totally added only before the last mill and as usual following compound imbibition system by circulating the admixture of juice and water on the cane chute before it enters the crusher. In that case derivation of formula will be as follows :—

$$\text{In the case } r = \frac{W m}{f(1 - m) + W m}$$

Where r = extraction.

W = added water per unit cane.

m = fibre per unit bagasse.

f = fibre per unit cane.

Usual formula for total secondary extraction runs as

$$e_s = r \left(\frac{(1 - r)^n - r^n}{(1 - r)^{n+1} - r^{n+1}} \right)$$

Where n = number of secondary units.

r = extraction.

However this will have to be modified by considering all the units as secondary units. And hence

$$e_s \text{ will be } = r \left(\frac{(1 - r)^{n+1} - r^{n+1}}{(1 - r)^{n+2} - r^{n+2}} \right)$$

Now, assuming certain figures, $m = 0.50$, $f = .12$ & $W_1 = 0.04$

$$\text{Primary Extraction} = e_p = \frac{m + mW_1 - f}{m(1 - f)}$$

(With simple imbibition & addition of water at 1st mill)

$$= \frac{0.50 + (0.50 \times 0.04) - 0.12}{0.50(1 - 0.12)}$$

$$= \frac{0.50 + 0.02 - 0.12}{0.50 \times 0.88}$$

$$= \frac{0.52 - 0.12}{0.4400}$$

$$\frac{0.40}{0.44} = 0.9090$$

$$\text{Primary Extraction} = e_p = \frac{m - f}{m(1 - f)}$$

$$\frac{0.50 - 0.12}{0.50(1 - 0.12)} = \frac{0.38}{0.44}$$

$$\frac{0.8636}{0.44}$$

Total extraction with new formula :—

$$e = r \left(\frac{(1 - r)^{n+1} - r^{n+1}}{(1 - r)^{n+2} - r^{n+2}} \right)$$

Where n = no. of secondary units.

r = extraction.

$$\text{Now } r = \frac{Wn}{f(1 - m) + Wm}$$

$$\begin{array}{l} | \quad W = 15\% \\ | \quad m = 50\% \\ | \quad f = 12\% \\ | \quad n = 2 \end{array}$$

$$\frac{0.15 \times 0.50}{0.12(1 - 0.5) + 0.15 \times 0.50}$$

$$r = \frac{0.075}{0.06 + 0.075}$$

$$= \frac{0.075}{0.135} = 0.555$$

$$\therefore e = 0.55 \left(\frac{(1 - 0.55)^3 - 0.55^3}{(1 - 0.55)^4 - 0.55^4} \right) \quad \text{with } n = 2$$

$$= 0.55 \left(\frac{0.091 - 0.166}{0.041 - 0.0915} \right)$$

$$= 0.55 \left(\begin{array}{l} + 0.075 \\ \hline + 0.050 \end{array} \right)$$

$$= \frac{0.04125}{0.050} = 8250$$

$$e = 0.55 \left(\begin{array}{l} (1-0.55)^5 - 0.55^5 \\ \hline (1-0.55)^6 - 0.55^6 \end{array} \right) \quad \text{with } n = 4$$

$$= 0.55 \left(\begin{array}{l} 0.01045 - 0.05032 \\ \hline 0.00470 - 0.02768 \end{array} \right)$$

$$= 0.55 \left(\begin{array}{l} + 0.03987 \\ \hline + 0.2298 \end{array} \right)$$

$$= \frac{0.0219}{0.02298}$$

$$= 0.9563$$

$$\text{Total Secondary Extraction} = e_s = r \left(\begin{array}{l} (1-r)^n - r^n \\ \hline (1-r)^{n+1} + r^{n+1} \end{array} \right)$$

(In normal compound imbibition system).

$$\text{Now } r = \frac{w m}{f(1-m) + w m}$$

$$= \frac{0.15 \times 0.50}{0.12(1-0.5) + (0.15 \times 0.50)} = 0.555$$

$$\therefore e_s = 0.55 \left(\begin{array}{l} (1-0.55)^2 - 0.55^2 \\ \hline (1-0.55)^3 - 0.55^3 \end{array} \right) \quad \text{with } n = 2$$

$$= 0.55 \left(\begin{array}{l} 0.2025 - 0.3025 \\ \hline 0.09113 - 0.16637 \end{array} \right)$$

$$= 0.55 \left(\begin{array}{c} + 0.1000 \\ \hline + 0.07524 \end{array} \right)$$

$$= \frac{0.055}{0.075} = 0.7333$$

$$\therefore c_s = 0.55 \left(\begin{array}{c} (1 - 0.55)^4 - 0.55^4 \\ \hline (1 - 0.55)^5 - 0.55^5 \end{array} \right) \quad \text{with } n = 4$$

$$= 0.55 \left(\begin{array}{c} 0.041 - 0.915 \\ \hline 0.01845 - 0.050328 \end{array} \right)$$

$$= 0.55 \left(\begin{array}{c} + 0.050 \\ \hline + 0.032 \end{array} \right)$$

$$= \frac{0.0275}{0.2320} = 8594$$

With formula**With new formula**

- (1) Primary Extraction.
(Simple imbibition)

86.36

90.90

- (2) Secondary Extraction
Compd. imbibition
with $n = 2$

73.33

82.50

- (3) With $n = 4$

85.94

95.63

New some of the assumptions made above will have to be experimently varified and than only final conclusion can be drawn. One thing is beyond doubt that this system will definitely be benificial as it appears apprently when put in the mathematical formula. But it is felt that the factories which are having shredder will be benifitted more as there will be effective imbibition before the prepared cane reaches the crusher. We also

propose to take further trials in the matter by seaking cut cane in water and judging the gain in weight. This will give an idea of water to be added in primary extraction. These results might indicate that whatever maceration, we are following at present might be either insufficient or some times unnecessary also when viewed through this new perspective plan. It may sound Queer to add water on the cane before it reaches the crusher because, the popular convention and belief is that, only after dry miling on the

crusher, the residul juice can be better extracted by spraying water over the mills. But we find that even before this dry milled bagasse is to be treated with water in the ultimate mill, we do treat it with admixture of juice and water. In that there should not be any objection for admition of such mixture on prepared cane from the shredder. The results obtained by this method of compound imbibition, will solely depend upon cane preparation, before the crusher. Presence of shredder, in this case will give better results.

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NEW METHOD OF COMPOUND IMBIBITION PART II

By

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ABSTRACT

On taking Laboratory and factory trials, it is confirmed that there is marginal increase in Primary Extraction after giving maceration water over the crusher after the shredder. Further it is found that there is reduction in bagasse pol which indirectly confirms the increase in mill extraction by this addition of water over the crusher. There is no additional equipment involved and it is suggested to make small modification in maceration water connections and see the results.

It is already advocated in Part I, to add maceration water on the crusher by either of the following three ways : -

- 1) By diverting some of the maceration water to the crusher.
- 2) By increasing straight away the maceration by adding extra water on the crusher.
- 2) By circulating whole of the maceration water back on the crusher instead of the 1st mill as it is done today.

But before looking into the advantages of

this type of maceration which has been already mathematically proved in Part I, it will be necessary to study the nature of sugar cane - rather the inside picture of sugar cane. The mature sugar cane received by the factory may not have any empty space inside its walls. But that is not true, Gupta and coworkers have already proved that the sugarcane has got empty space in the form of some empty cell saps. In light of these facts, so as to confirm these observations, some of the cane was cut and soaked in water and it was found that the mature cane gains in wt. after being soaked in water. Following reading were taken on laboratory scale to confirm this fact,

Table—1

Item	Wt. before adding of water.	After soaking for 5 ml.	Remerk.
Cane	92 gm.	150 gm.	Shredded cane was taken throughout the observation.
	60 gm.	96 gm.	
	79 gm.	125 gm.	
	46 gm.	94 gm.	
	58 gm.	104 gm.	

Laboratory trials for bagases pol were conducted as follows : —

- 1) The bagasse pol for the cane was found by dry milling on laboratory crusher.
- 2) The can was schredded and put in the mills and the bagasse pol was found out.
- 3) The schredded cane was macerated with definite quantity of water and the bagasse pol was found.

Table-2

Item	Bagasse Pol with dry milling.	Baga. Pol with shredded cane	Baga. Pol with macerated schredded cane
1.	7.0	6.2	5.6
2.	6.8	6.2	5.2
3.	6.4	6.0	5.2
4.	7.2	6.4	5.4
5.	7.0	6.2	5.2

After confirming the facts on laboratory scale, a trial was conducted on commercial scale in Shetkari S. S. K. Ltd; Sangli during the season of 1975-76. The factory had two mill tendams and the trials were conducted on one of the mill tendam consisting of six mills. The maceration water sprayed on the ultimate mill was partly diverted to the crusher after the shredder. Thus fresh water was added on the cane after the shredder and before the crusher. This quantity of water sprayed was measured. When the observation were made, the factory was continuing crushing with average maceration % cane of 18. Out of this about 4% was diverted towards crusher maceration and the remaining maceration was carried on by say 14%. These trials were conducted for about 4 hours per day for 5 days. As we did not want to disturb their usual routine, the trials were conducted only for 4 hrs in a day. The ultimate bagasse pol, obtained from the observations made it is clear that addition of water on the crusher gives reduction in bagasse pol at the ultimate mill. There is appreciable rise in primary extraction by following the process and from the observations it will be clear that since the water was sprayed on the crusher there was rise in primary extraction resulting in reduction in bagasse pol from the crusher. Usual bagasse pol from the crusher was throughout more than 10, whereas, with maceration, it

was below 10. It was mostly argued that increase in Primary Extraction, may be followed by decrease in secondary extraction resulting in keeping the total extraction as the same. But it is observed that effective maceration takes place, due to diversion of some of the maceration water on the crusher, soon after the shredder. Cane preparation is definitely a deciding factor over here and factories having a shredder only can try this.

However, all these observations could be taken only for a week. It is proposed to run the mills following all the three ways stated above for maceration, on some mill for about a month and then draw firm conclusions. Those having a shredder can try this without much loss or extra mechanical arrangement, except for making some minor piping arrangement and see the results.

Acknowledgements

We thank the management of Shetkari, S. S. K. Ltd. Sangli for allowing us to make these observations. Our special thanks are to Shri M. S. Dabhole, Chief Engineer, Sangli who made the necessary pipe connections. We thank Principal, Govt. Polytechnic for allowing to conduct this study and Shri V. R. Aswale our trainy Chemist who helped us in Lab. work.

After macerating the crusher was regularly found to be lower than the bagasse pol found by usual method of maceration after the crusher. The observations made were as follows :—

Table—3

**Analysis of Bagasse and Juice During the Trial of Improved Method of Imbibition
at Shetakari S. I. S. K. Ltd. Sangli,**

Date	Primary Bagasse		Final Bagasse		Primary Juice.		Last expressed		Juice.	
	Moisture	pol.	Moisture	pol.	Bx.	Pol.	Pty.	Bx.	Pol.	Pty.
23-12-75										
With maceration.	59.00	9.4	50	2.3	18.92	16.57	87.58	3.20	2.32	74.34
Without macer.	55.00	10.00	50	2.6	19.38	17.30	89.26	3.78	2.93	77.59
24-12-75										
With macer.	60.00	9.6	48	2.2	19.25	17.5	90.96	3.80	2.93	76.30
without macer.	57.00	10.6	49	2.5	20.82	18.69	89.76	3.60	2.79	77.50
25-12-75										
With macer.	55.00	9.7	50	2.2	19.72	17.78	91.17	3.90	2.93	80.93
Without macer.	56.00	10.5	50	2.6	20.55	17.92	87.20	3.91	2.99	76.47

Contd.

Date	Primary Bagasse		Final Bagasse		Primary Juice		Last expressed Juice.			
	Moisture	Pol.	Moisture	Pol.	Bx.	Pol.	Bx.	Pol.	Pty.	
26-12-75										
With macer.	55.00	9.6	50	2.3	19.37	16.67	86.60	3.80	2.41	69.65
Without macer.	57.00	10.4	49	2.5	20.38	17.97	88.17	3.16	2.37	75.00
27-12-77										
With macer.	55.00	9.3	50	2.3	20.82	18.52	88.95	3.64	2.80	76.92
Without macer.	55.00	10.5	49	2.5	20.22	17.80	88.03	3.80	2.90	76.31
28-12-77										
With macer.	55.00	8.9	50	2.10	18.48	15.96	86.36	3.74	2.79	74.59
Without macer.	57.00	10.0	49	2.50	20.02	17.60	87.91	3.72	2.84	76.34

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PHOSPHATASION OF UNFILTERED SECOND CARBONATION CANE JUICE : - DEVELOPMENT OF A NEW SYSTEM OF CANE JUICE CLARIFICATION FOR MANUFACTURE OF SUPERIOR QUALITY SUGAR AT REDUCED MANUFACTURING COSTS

PART-II-FACTORY SCALE TRIALS

By

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ABSTRACT

In first part of the paper physico-chemical characteristics of phosphoric acid treated unfiltered second carbonation juices were presented. The newly developed process "phospho carbonation" was also tested on pilot plant scale. The results of these trials were also published in the first part. In this part of the paper factory scale trials of the process at Kichha Sugar Company Ltd., Kichha, Nainital, in the season 1977-78 are presented alongwith techno-economy feasibility of the new process.

Introduction

Findings of laboratory investigations at Doiwala, Rohana Kalan and Kichha into the physico chemical properties of phosphated second carbonation juices were discussed in an earlier presentation (1). On the basis of

these finding a new technology known as "phospho-carbonation" aimed at elimination of second filtration and sulphitation from the conventional system of DC & DS was developed. Pilot Plant trials of the phospho-carbonation and results of the performance of low retention continuous subsider were also pre-

sented in the same paper. The present communication result to the details of the technology, the design aspects of the equipment, performance of the industrial unit at Kichha in the season 1977-78 and techno-economic feasibility of the new process.

"Phospho-Carbonation" Process

Phospho carbonation process (Fig. 1) consists of heating of raw juice to 55° C, continuous return of subsider muddy juice consisting of composit CaCO_3 $\text{Ca}_3(\text{PO}_4)_2$ ppt. to raw juice and preliming to 6.6 - 6.8 pH in primary continuous prelimer followed by second pre-liming to 10.5 pH in the secondary continuous prelimer and first carbonation like coventional system followed by low pressure filtration in plate and frame filter presses or in thickner filter-continuous vacuum filter combination. The filtered juice is carbonated to a pH level corresponding to minimum CaO content in continuous second carbonators and heated to 70°C as in conventional DC & DS but unlike the conventional system the heated juice instead of being filtered is subjected to two stages of continuous phosphatation in two continuous chemical reactors. (For details please refer Fig - 3). In the primary continuous reactor the heated second carbonation juice is phosphated by recirculated muddy juice consisting of CaCO_3 - $\text{Ca}_3(\text{PO}_4)_2$ composit ppt. from continuous subsider. $\text{Ca}_3(\text{PO}_4)_2$ ppt. of the muddy juice envelops the suspended CaCO_3 ppt. of second carbonated juice and gives a protective coating on them. CaCO_3 particles with this protective coating overflow to the secondary reactor where the juice is further phosphated

to neutrality either by dilute phosphoric acid (10%) or by aqueous clear aliquot of triple super-phosphate obtained by dissolving T.S.P. in boiling condensates and decating in a storage tank. $\text{Ca}_3(\text{PO}_4)_2$ ppt. formed as a result of neutralization of the juice deposits on the existing ppt and gives heavy and voluminous flocs consisting of CaCO_3 ppt surrounded by voluminous and gelatinous $\text{Ca}_3(\text{PO}_4)_2$ ppt. This coating of CaCO_3 particles by $\text{Ca}_3(\text{PO}_4)_2$ in both the continuous phosphatation reactors avoids CaCO_3 coming in direct contact of phosphoric acid. The phosphated juice at 7.1 pH enters the flocculating compartment at the top of the low retention continuous subsider where from any foam formed in the phosphate reactors is continuously swept out by hinged scraper blade into the foam canal and therefrom to primary prelimer alongwith the returned mud. Flocculated and defoamed juice enters the sludge bed at the bottom of the clarifier through the central feed pipe. The sludge bed is uniformly loaded by equitable withdrawal of the settled juice from the top of the settling zone through a number of concentric perforated pipes and 4 number of collecting radial pipes terminating into 4 number of juice overflow boxes situated at 90° from the centre of the clarifier. A particular level of sludge bed is maintained by regulating mud withdrawal. In the sludge bed due to slow motion of the rakes the flocs get additional opportunity of collasence and any fragments of $\text{Ca}_3(\text{PO}_4)_2$ which have escaped union with CaCO_3 ppt get entrapped in the sludge bed giving clarified juice free of any turbidity. Part of the settled mud is continuously recirculated into primary

phosphate reactor and part of the mud along-with foam is continuously recycled into primary prefilter. The clarified juice goes to multiple effect evaporators through the clear juice preheater.

This process differs from the carbonation phosphatation process tested on pilot plant by Taiwanese workers (3) in to significant aspects. Carbonation phosphatation process involves third filtration and use of flocculating agents and filter aids in addition to phosphoric acid while in the new process not only this additional filtration and use of flocculating agents and filter aids is avoided but even second filtration is removed. And in addition to saving in costs and reduction of sugar losses in second and third filtration the consumption of lime at first carbonation is expected to be reduced due to return of muddy juice of the clarifier containing CaCO_3 ppt. of second carbonation and return of the phosphates to raw juice. The extent of additional clarification obtained over and above second carbonation in the new process is as good as reported by Taiwanese worker since all the phosphoric acid used goes into production of protective coating of $\text{Ca}_3(\text{PO}_4)_2$ by reacting with Ca ions in solution. Consumption of phosphoric acid is none the more than the process tested by Taiwanese workers. These findings were confirmed in laboratory investigation as well as in pilot plant trials already reported in the first part.

Industrial Scale Trials

After successful pilot plant trials of the strategic aspects of the new process at Rohan a

Kalan in 1976-77 crushing season, Techno-economic feasibility of the process were studied on industrial scale at Kichha during 1977-78 crushing season. Industrial model of the phosphate reactors and continuous subsider for phospho-carbonation juice was designed, fabricated and commissioned towards the end of 1977-78 crushing season. The details of the equipment are shown in Fig. 2.

The clarifier with 30 minutes retention time could treat as much as 700 tonnes of juice per hour. The units was commissioned on 24-6-78 and hourly samples of clarified juice from the clarifier were compared with corresponding samples of clarified juice obtained by the conventional DC & DS being worked on the balance quantity of factory juice (about 500-800 tonnes) Daily averages of these are tabulated in table - I.

These large-scales trials conducted even during most unfavourable conditions of the season had a very smooth going and achieved the same improvement over D. C. & D. S. process as noticed during laboratory and pilot plant testings (1). Phospho-carbonation gave an average of 1.5 units additional purity rise, further reduction of 170 mg. of CaO /litre, reduction in ash content, and reduction in colour content by 12.5%. Clarified juice obtained by new process was further compared for some additional technical parameters like sucrose purities, reducing sugar contents and phosphate contents. Some typical data are reproduced in table II. These provide additional evidence of superior quality of juice obtained by new process. Additional removal of CaO content and ash results into true purity rise. The destruction of R. S. which

continues beyond first carbonation stage in the conventional system is arrested in the new process as is evident from R. S. contents data presented in table II. Most of the phosphoric acid added is precipitated as $\text{Ca}_3(\text{PO}_4)_2$ as is evident from P_2O_5 content, data in table II. The increase in P_2O_5 content is as a result of conversion of carbonates of Na and K to their phosphate. These soluble phosphate salts are expected to reduce scaling problems, reduce colour development in post clarification operations and improve exhaustibility of molasses. Reduced destruction of R. S. is expected to improve exhaustibility. The clarified juice obtained by the new process having higher purity, higher R. S. higher P_2O_5 content and lower colour and ash content is expected to produce sugar of lower colour

and free of SO_2 and of better keeping quality. Sugar produced during the trials of the process was found to be more sparkling and lighter in colour. The gain in extra recovery is expected to be higher than estimates made by SJM formula due to higher RS/ash ratio in clarified juice obtained by phospho-carbonation juices.

Economic Feasibility

Having established the technical feasibility it is now necessary to examine the economics of the new process. On the basis of the above industrial trials it has been possible to examine this aspect. The economic analysis on the existing crushing capacity and duration of the season at Kichha works out as under :—

Daily crushing capacity	2000 Tonnes
Capacity utilisation per crop day	90%
Duration of the season	200 days
Phosphoric acid consumption	0.04 % cane
Saving in sulphur consumption	0.02 % „

Saving

(1) *Extra Gain in Recovery* :—Applying SJM formula on the average juice purities during trials (Table—I) and taking actual molasses purities and 100% clear juice on cane the estimated recoveries in the new process and conventional process work out as under :—

$$\begin{array}{l} \text{Estimated recovery} \\ \text{from phospho-carbonation} \\ \text{process.} \end{array} = 9.20 \times \frac{100 (80.77 - 36.73)}{80.77 (100 - 36.73)} = 7.93\% \text{ cane}$$

Estimated recover from

D. C. & D. S. process.

$$= 9.13 \times \frac{100 (79.39 - 36.73)}{79.39 (100 - 36.73)} = 7.75 \% \text{ cane}$$

Extra recovery with the new process over the conventional one = 0.18 % cane

$$= 0.18 \% \text{ cane}$$

@ Rs. 200/- per qtl.)

$$= \text{Rs. } 6480/- \text{ per day}$$

Extra Sales realisation due to sugar of superior colour and of better keeping quality (assumed @ 2/- premium per qtl. and sugar recovery of 9.5 % cane).

$$\text{Rs. } 3420/- \text{ per day}$$

Habour saving at second filter presses ($10\frac{1}{2}$ per day @ Rs. 300/- p.m.) $10\frac{1}{2}$ workers.

$$= \text{Rs. } 105/- \text{ per day}$$

Saving in filter cloth, steam and miantenance @ 20 paise per tonne cane)

$$= \text{Rs. } 360/- \text{ per day}$$

Saving of sulphur 0.02% cane

$$\text{Rs. } 360/-$$

$$\text{Total} \quad \text{Rs. } \underline{\underline{10,725/-}}$$

Extra Expenditnre

(1) Cost of phosphoric acid (0.04 % cane and 7000/- per tonne cost of acid)

$$\text{Rs. } 5040/-$$

(2) Labour cost $3\frac{1}{2}$ workers per day

$$\text{Rs. } 35/-$$

$$\text{Total} \quad \text{Rs. } \underline{\underline{5075/-}}$$

Daily Savings

$$= \text{Rs. } 5650/-$$

Annual Saving

$$= \text{Rs. } 11,30,000/-$$

Discussion

1. Neutralisation of second carbonation juice before filtration in phospho-carbonation process is no doubt unconventional and on the outset may appear to be entirely unscientific yet the same forms the crux of the new process and therefore, deserves intensive investigations as is evident from earlier publication (1). These studies were undertaken for studying adverse side reactions or any Lacuna in the proposed process. Investigations carried out in laboratories, in pilot plant and industrial scale equipment led to the following conclusion :—

(i) Anions of phosphoric acid behave in quite a different fashion than their counterparts of other mineral acids (e. g. sulphurous, sulphuric and hydrochloric). During the course of neutralization of unfiltered second carbonation cane juices phosphations react with calcium ions of the liquid phase and form sparingly soluble $\text{Ca}_3(\text{PO}_4)_2$ till concentration of Ca in liquid phase reduces to the level corresponding to the solubility product of $\text{Ca}_3(\text{PO}_4)_2$. In case of other mineral acids say sulphurous acid the calcium salts of the neutralizing acid are highly soluble resulting into redissolution of CaCO_3 particles.

(ii) In addition to insolubility of $\text{Ca}_3(\text{PO}_4)_2$ the ppt. possess very high surface weight ratio. The surface is highly reactive and adsorbs on its surface colloids and colouring matter. This ppt. also possess high negative charge and is readily attracted towards tiny particleless of CaCO_3 which are reported to be positively charged. CaCO_3 particles thus get protective coating of $\text{Ca}_3(\text{PO}_4)_2$

and this coating gets on increasing with progress of neutralization and inspite of decrease in pH, precipitated CaCO_3 of second carbonation does not redissolve as is evident from continuous reduction in CaO content, colour and salts with the progress of neutralization. Photomicrographic examination at 1000 x also throws a strong evidence in favour of such a mechanism of Co-precipitation of $\text{Ca}_3(\text{PO}_4)_2$ (1). Recirculation of settled ppt. to phosphate reactor in the industrial scale model of the equipment affords additional opportunity for these physico chemical reactions and the protective coating given to the CaCO_3 ppt. before addition of phosphoric acid insures against any accidental redissolution of CaCO_3 ppt.

(iii) The conjoint ppt. of CaCO_3 and $\text{Ca}_3(\text{PO}_4)_2$ is fairly stable and can tolerate to a fairly large extent the mechanical handling of the phospho-carbonated juices without any evidence of rupturing of the attractive and binding forces between CaCO_3 and $\text{Ca}_3(\text{PO}_4)_2$ ppts. This conjoint ppt. possess remarkably improved physico chemical properties. CaCO_3 ppt. of second carbonation is extremely fine and does not settle and filters with some difficulty. $\text{Ca}_3(\text{PO}_4)_2$ ppt. due to its voluminous nature settles with great difficulty and both the phosphated juice as well as settled muds filter with extreme difficulty. Contrary to these the ppt. obtained in phospo-carbonation settles extremely fast which require very small settling area and settling volumes of a clarifier. The settled muds are fairly compact and their return to raw juice beneficially helps in improving both the filterability and clarificability of first carbonated juices.

Return of the mud to raw juice is also expected to reduce the lime consumption atleast by an amount of Ca precipitated as CaCO_3 and $\text{Ca}_3(\text{PO}_4)_2$.

(iv) Composit ppt. of $\text{CaCO}_3 - \text{Ca}_3(\text{PO}_4)_2$ settles, extremely fast and retention of juices upto $1\frac{1}{2}$ hrs had no unfavourable effects on the quality of clarified juice. pH , of the clear juice remains constant and there is only very slight rise in reducing sugars. CaO contents show a further drop. On the basis of these tests the industrial clarifier has been designed for retention time of half an hour only.

2. The industrial scale trials of the process at Kichha since 24.6.78 to 15.7.78 established the technical feasibility of the new process. These sustained trials gave consistent quality of clarified juice of higher purities, lower CaO content, lower ash and colour than the clarified juice obtained from conventional D. C. and D. S. process. Lower colour of the juices was reflected on the quality of sugar manufactured during this period which was more lustrous and lighter in colour than that manufactured earlier indicating clearly that sugar produced exclusively from the new process would be still superior.

3. Destruction of R. S. is very prominent in conventional system. The decomposition reaction goes even beyond second carbonation filtered juice as is evident from the analyses of the sulphited juices and filtered first carbonated juices (Table-II). These observations have been reported by other workers also (2). In the new process the destruction of R. S. is immediately arrested after the second carbonation. Higher reducing sugar contents are expected to improve the exhaustibility of

molasses and increase sugar recovery beyond estimates on the basis of SJM formula worked out presently.

4. Estimation of phosphate contents in the juices reveal that most of the phosphate ions added to second carbonated juice is removed as $\text{Ca}_3(\text{PO}_4)_2$ and the balance goes to convert carbonates of K, Na and Ca into their respective phosphates. The presence of these phosphates inhibit colour formation in post clarification stages and unlike sulphites the colour inhibition is permanent and is expected to give sugars of better keeping quality. The presence of these phosphates is also expected to reduce scaling in evaporators.

5. Many of the technical advantages which the new process promises could not be quantified with short duration of the industrial trials but even at that the financial estimates made on the basis of extra recovery and production of superior quality of sugar free of SO_2 forecasts additional annual profits to the extent of 11.30 lakhs for Kichha Sugar Company.

Acknowledgement

Author gratefully thanks Shri N. M. Majumdar, I. A. S., Chairman, U. P. State Sugar Corporation and Directors of Kichha Sugar Co. for their kind permission to take up the project on industrial scale. Grateful thanks are also due to Shri N. R. Banerji, I. A. S. Managing Director, of U. P. State Sugar Corporation for his permission to publish the present work. Thanks are also due to sarve Shri B. K. Singh, Executive Director, Shri Randhir Singh, Chief Chemist and other technical staff of Kichha Sugar Co. for their co-operation through out the present work.

Fig. 2 (Contd) "Phospho-Carbonation" Details.**(1) Continuous Primary Phosphate Reactor**

- (a) Heated second carbonation juice entry through inlet nozzle.
- (b) Muddy juice inlet
- (c) Circulating nozzle
- (d) Circulation cone
- (e) Overflow pipe

(2) Continuous Secondary Phosphate Reactor

- (f) Inlet nozzle
- (g) Circulating nozzle
- (h) Overflow of phosphate reactor and tangential entry into flocculating chamber of continuous subsider.

(3) Phospho-Carbonation Low Retention Continuous Subsider

- (i) Hinged plate for sweeping out foam
- (j) Foam canal
- (k) Stirrer arm for supporting plate (i)
- (l) Hinged scrapers for sweeping out settled muds
- (m) Central feed pipe
- (n) Circular baffle plate attached top
- (o) Stirrer arms
- (p) Central drive shaft
- (q) Circular concentric perforated juice outlet pipes
- (r) Juice collecting radial mains
- (s) Clear juice overflow boxes

- (t) Muddy juice overflow box for muddy juice return to phosphate reactor.
- (t-1) Muddy juice overflow box for muddy juice return to preliimer.

(u) Mud cocks

(v) Sump tank

(4) Phosphate Proportioner

(a) Entry of phosphoric acid

(b) Overflow

(c) Telescopic pipe

(5) Reduction Gear and Moter Drive for Drive Shaft p

(6) Muddy Juice Recirculation Pump to Prelimer

(7) Muddy Juice Recirculation Pump to Phosphate Reactor

TABLE I

**Comparison of Juice Qualities of Clarified Juice from Phospho-Carbonation
Double Sulphitation System (Aver-**

D a t e s	Phospho-		Carbonation		subsider			juices	
	Bx	Pol	Purity	pH	CaO Con- tent(mgm /lit.	Optail density	Conducti- vity (Mohs/ Cm ³)		
24.6.78	11.23	8.91	79.34	7.15	1075	—	—		
25.6.78	11.64	9.42	80.93	7.15	1120	—	—		
26.6.78	10.76	8.65	80.39	7.13	1002	—	—		
27.6.78	11.65	9.60	82.47	7.13	974	0.310	3.728X	10 ⁻³	
28.6.78	11.31	9.22	81.52	7.07	1117	0.402	3.775X	10 ⁻³	
29.6.78	11.56	9.37	81.06	7.10	1106	0.357	4.054X	10 ⁻³	
30.6.78	11.10	8.93	80.45	7.10	1122	0.268	3.355X	10 ⁻³	
1.7.78	11.88	9.50	79.97	7.10	1187	0.346	3.821X	10 ⁻³	
Average	11.39	9.20	80.77		1088	0.337	3.747X	10 ⁻³	

**System with Conventional Thin Sulphited Juice From Double Carbonation
ages of Hourly Samples)**

Sulphited		juices		from	D. C. & D. S. process		
Bx	Pol	Purity	pH	Cao	Cantent	Optical density	Conductvity (Mohs/Cm ³)
11.46	8.92	77.84	7.00	1172	—	—	—
11.68	9.30	79.62	7.08	1229	—	—	—
10.76	8.57	79.65	7.00	1134	—	—	—
11.67	9.47	81.15	7.21	1125	0.403	3.961X 10 ⁻³	
11.46	9.19	80.19	7.07	1266	0.394	4.147X 10 ⁻³	
11.84	9.45	72.81	7.00	1225	0.456	4.054X 10 ⁻³	
11.20	8.80	79.28	7.10	1301	0.340	4.334X 10 ⁻³	
11.92	9.41	79.94	7 00	1300	0.331	4.241X 10 ⁻³	
11.50	9.13	79.39		1220	0.385	4.147X 10 ⁻³	

TABLE-II

Comparison of Juice Qualities of Phospho Carbonated Settled Juice

Dates	PARTICULARS	Bx	Pol.	Purity	Sucrose %
13.7.78	Raw Juice	12.76	8.84	69.28	9.02
	Filtered 1st carbonation	11.36	8.30	73.10	8.46
	Phospho carbonated clear juice	10.86	8.22	75.69	8.56
	Sulphited thin juice	10.86	8.02	73.85	8.48
15.7.78	Raw Juice	12.76	8.74	68.50	—
	Filtered first carbonated	11.56	8.25	71.37	—
	Phospho-carbonated clear juice	11.67	8.57	73.44	—
	Sulphited thin juice	12.07	8.76	72.58	—

* High CaO content in clarified juice due to processing of stale cane and use of rejected rains.

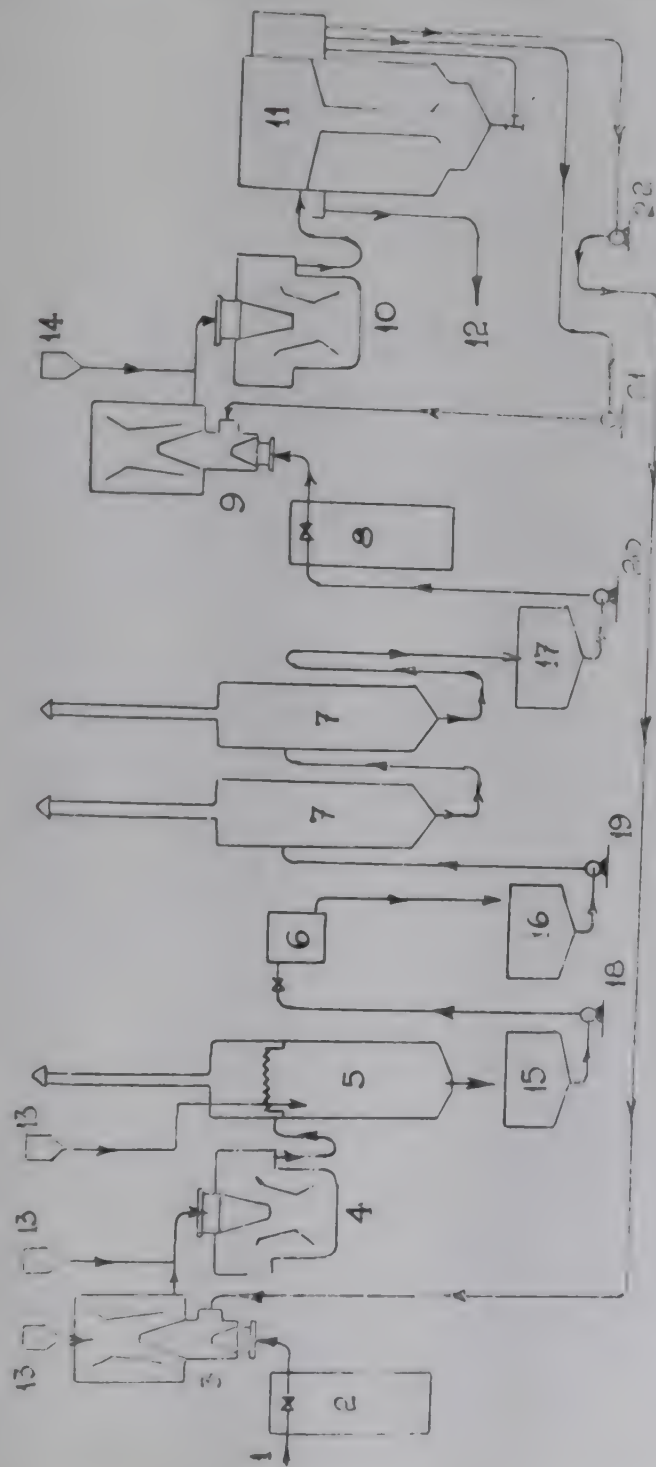
with Sulphited Thin Juices From D.C. & D. S. Process (Spot Samples)

Sucrose Purity	CaO Content (mgm/lit.)*	R.S. per liter per 100Bx	Conductivity (Mohs/cm ³)	Phosphate content mgm/lit.	pH
70.69	1120	—	4.194X 10 ⁻³	650	5.5
74.47	2080	8.45	4.660X 10 ⁻³	60	10.2
78.82	1780	8.52	4.185X 10 ⁻³	100	5.9
78.08	1950	6.90	4.194X 10 ⁻³	87	7.0
—	1670	12.96	5.126X 10 ⁻³	680	5.3
—	2000	8.53	4.660X 10 ⁻³	85	10.2
—	1380	10.22	4.893X 10 ⁻³	120	6.9
—	1710	7.72	4.893X 10 ⁻³	50	8.9

lots of lime stone from Rajasthan due to non arrival of Dehra Doon lime stone due to heavy

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SCHEMATIC FLOW DIAGRAM OF PHOSPHO-CARBONATION SYSTEM

- | | | | |
|----|--|----|--|
| 1 | RAW JUICE INLET | 18 | PUMPS FOR FIRST CARBONATED, FILTERED, SECOND CARBONATED, SUBSIDER MUDDY JUICE CIRCULATION TO PHOSPHATE REACTOR AND CONTINUOUS PRELIMER |
| 2 | RAW JUICE HEATER | 19 | |
| 3 | PRIMARY CARBONATOR | 20 | |
| 4 | SECONDARY CARBONATOR | 21 | |
| 5 | FIRST CARBONATORS | 22 | |
| 6 | FILTERS | | |
| 7 | CONTINUOUS SECOND CARBONATORS | | |
| 8 | SECOND CARBONATION JUICE HEATER | | |
| 9 | CONTINUOUS PRIMARY PHOSPHATE REACTOR | | |
| 10 | CONTINUOUS SECONDARY PHOSPHATE REACTOR | | |
| 11 | LOW RETENTION PHOSPHO CARBONATION SUBSIDER | | |
| 12 | CLEAR JUICE OVERFLOW | | |
| 13 | LINE DOSERS | | |
| 14 | PHOSPHATE DOSER | | |
| 15 | RECEIVING TANKS FOR FIRST CARBONATED, FILTERED AND SECOND CARBONATED JUICE | | |
| 16 | | | |
| 17 | | | |

FIG. 1



FIG. 2.

EFFICIENT WORKING OF LIME KILN-DESIGN, QUALITY & OPERATIONAL ASPECTS

By

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ABSTRACT

Lime kiln is a vital station of a carbonation sugar factory having the significance of backbone for its process operations. As the bulk requirements of lime have to be produced at site by calcining limestone in the lime kiln, its working directly reflects on the economics of the plant and ultimately on the production cost of sugar. Efficient working of lime kiln is greatly influenced by three factors vize., Design features of the kiln, quality of the limestone fed to it and operational conditions. By incorporating advantageous design improvements wherever possible, coupled with judicious control and proper care of the quality of limestone and operational conditions, the cost of lime production can successful be minimised and at the same time smooth process operation can be ensured.

Introduction :

Lime is one of the most important and major chemicals used for purification of juice in sugar-manufacture with varying requirements according to the process adopted for clarification. More than any other process, it assumes greatest significance in the factories following Mixed Juice Carbonation process of clarification where its consumption is almost ten times more as compared to Sulphitation

Factories. Despite its higher installed & working cost, the carbonation process found favour as a superior method of juice purification as it enables greater elimination of Non-sugars than Sulphitation and in turn provides an answer to demand for bold grain white plantation sugar with sparkling white colour. Secondly, it has capacity to handle with ease, the clarification of "REFRACTORY JUICES" having complex characteristics causing difficulty at the clarification stage. The higher

working cost is partly recovered in better quality of sugar and partly by a higher recovery obtainable in a properly controlled carbonation process owing to higher elimination of non-sugars so higher rise in purities of juice at clarification stage. The economics of Carbonation process got a further boost by introduction of "Mud-Thickness & Vacuum Filter" & G. P. Filters plugging the biggest hole of sugar loss through filter presses in the conventional carbonation process. As the CO_2 Gas necessary for Carbonation is produced, at the same time as lime, kilns are a common sight in Carbonation Factories.

The modern tendency is to put the accent on the purification of the sugar, more than on a better clarification of the juice. Remelting of sugar sustained by a purification process of melt give better results with lower expenditure than conventional methods of relying on juice purification for achieving better quality of sugar. One of these melt purification processes involves Carbonation of melt & hence accounts for commissioning of a lime kiln.

In the India Sugar Industry, barring one factory which practises Middle Juice Carbonation process of clarification, all the Factories adopt either of the two conventional processes of juice purification. In a Carbonation Sugar Factory, the consumption of Lime Stone is about 3.0—3.5 per cent cane. the Upper limit rising to 4.0 & even to 4.5 in certain cases proper control is not exercised with care in the working of the lime kiln. With all round spiralling rise in the recent years in the cost of stores as also the cost of transportation coupled with intensive pressure on the Indian

Sugar Industry to achieve a drastic cut in production cost of sugar for retaining its' economic viability, the working of this station which alone accounts for a lion's share in the processing cost, needs to be critically examined especially in view of the rising expenditure on its' maintenance & working which is quite inconsistent with the needs of the time & hence deserves utmost attention. In this paper an attempt has been made to discuss all important aspects that influence on efficient & economic working of Lime Kiln e. g. (i) Design (ii) Quality, (iii) Operational Conditions.

1. Design-Shape, Size & Construction of the Kiln :

(A) The Shaft Kiln :

The first lime kiln introduced into the cane sugar Industry was the continental shaft-kiln, a truncated cone of masonry lined on the inside with refractory brick consisting of a tapering masonry shaft of 40 to 50 ft. height, terminating at the top in a Cast Iron funnel closed by a lever controlled cone for charging the mixture of Lime Stone & hard-coke. It had three to four large openings at bottom closed by cast-iron doors for withdrawal of burnt lime besides additional-openings in the lower part to facilitate passage of combustion air & plug closed spy holes for inspection of the interior in different sides at varying heights along the shaft. This design, however posed operational difficulties and suffered a serious drawback that with passage of time masonry cracked & air drawn through cracks diluted Kiln Gas. As a consequence, it was discarded & replaced by Belgian or Khern type Lime Kiln towards the end of previous century.

(B) Belgian or Khern Type Lime Kiln :

This design in its original form or with some modifications, is most commonly seen in the Indian Carbonation Factories. This consists of a steel plate shell (or casing) lined with refractory bricks separated by an annular opening filled with pea size broken fire-clay bricks or kiessluhr insulating bricks. As shown in Fig. 2, it has the form of two obtuse cones joined together at their bases, the Upper and longest cone having at its top a steel funnel the centre opening of which is closed by a bell which can be hoisted to admit the fresh charge into the interior of the kiln. The lower inverted cone opens at the bottom side having a small steel cone underneath at the ground right under the discharge opening. This cone completely covered by the discharging lumps of the lime facilitates uniform discharge by shovelling from all sides & prevents accumulation of ash in the centre. This design, however, is also not free of short-comings. Tapering of undermost cone some times caused arching with the result that stickings of lime stone mass has to be rammed sustained by paking through sight-holes. This ramming generally cause heavy damage to the refractory & in many cases even then it is not successful leaving no other alternative but to wait till kiln is cooled down & the contents come down of their own. Another design drawback of Belgian Kiln generally experienced is that double cone form obstructs regular & even movement of the charge downwards inside the shaft as also a uniform distribution of combustion air through the whole length & width of the Kiln-Shaft.

Before considering any modification for improvement in the design or determining the most suitable dimensions of the kiln, a precise understanding of burning process would be advantageous. While working, the Lime Kiln comprises of three zones viz (i) Storing, drying & preheating zone in which fresh charge is heated by escaping kiln gases which in turn get cooled, (ii) Calcination zone where combustion & decomposition takes place & (iii) Cooling zone where lime lumps are cooled down by in-coming air which gets preheated by heat liberated by Lime. For efficient working of the kiln proper maintenance of these three zones is an essential requirement which can be achieved by maintaining uniform operational conditions the most important of them being regular & uniform charging of mixture & withdrawal from the kiln. When the lime lumps are not shovelled away uniformly at all sides the highest temperature zone will be lowered in one side. To promote uniform discharge & prevent any accumulation of ash, the Cone at the discharge point was replaced in some cases by a circular shift-bar-grate. (Fig. 2-A).

Further, to avoid arch formation due to tapering of undermost cone, it was replaced in many Belgian Kilns by a Cylindrical shaft which also increased the capacity of the kiln. This was first step in the right direction but not the complete solution with the existing design features of the Belgian Kiln which stipulated a ratio of Base-dia : height as 1:6 resulting in to low thermal efficiencies especially in small kilns where fuel to lime-stone ratio had to be increased.

(C) *Modern Cylindrical Lime Kilns :*

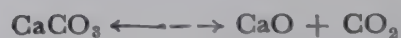
To overcome difficulties enumerated above the modern & simplest design of cylindrical lime kiln having the form of a straight vertical cylinder slightly tapering at the top was introduced which could afford a ratio of Base-dia : height as high as 1 : 9.

The modern tall cylindrical kilns (Fig. 3) have a definite advantage over Belgian Kilns of same capacity in the form of much smaller diameter rendering very high thermal efficiency & at the same time facilitating uniform distribution of the charge as it travels down the shaft over its' cross section. With the shape of funnel & the bell a 'classifying action' takes place owing to difference in the particle size & densities of Coke & Stones, the finer pieces having the tendency to localise at the centre while the larger pieces roll out-side the pile. This effect increases with larger diameter of the shaft & creates erratic burning in the kiln as the fire climbs to the top in one section & remains low in the other rendering 'Under-burnt' & 'Over-burnt' lime respectively. A modern lime kiln with provisions of automatic discharge by a rotary grate & mechanical charging by rotary stokerfeed, with proper instrumentation for controlling the temperature & draught of escaping kiln gases, is capable of giving most economical & efficient working results. However, where existing installations are to be retained, those can be suitably modified in the light of above discussions & provided with modern instrumental control to provide a "Technical Eye" for controlling operations. This would greatly improve the working conditions & hence efficiency of the station.

2. **Quality of Lime-Stone & Hard-Coke :**

Lime stone, which forms the largest single chemical used for sugar manufacture in Carbonation Process requires utmost attention in selection of its' quality suitable for burning process & processing as it influences to a very great extent, the working efficiency of the Kiln as well as processing parameters of the cane juice. Limestone, as its' name implies is the rock containing calcium carbonate, its main ingredient in varying proportions which alongwith the nature & amount of impurities present, determine its' suitability for various purposes. Lime Stone is not a pure chemical having Calcium Carbonate contaminated by various impurities, the main among them being clay, sand, Iron & Aluminium Oxide and Magnesium Carbonate. The proportion of the Calcium Carbonate it contains, decides its superiority in grade. For burning limestone in the Kilns & using it for sugar manufacture, highest grade limestone containing maximum CaCO_3 (Not less than 95%) & minimum impurities is ideally suited. It is for the reason that the presence of impurities in major proportions lays its deleterious effects on the burning process, slaking of lime & finally on the processing of the juice. For specifying quality requirements it would be important to understand the mechanism of lime stone in the Calcination Zone.

Calcium Carbonate on heating, dissociates into CaO & CO_2 according to following equation :



It is a reversible and endothermic reaction absorbing about 42.5 K. Cal Mo. Wt. The dissociation of Lime Stone begins at about 600°C but another factor controlling the rate of decomposition is the equilibrium pressure of CO_2 which is negligible at 650°C but increases rapidly to reach 1 atmospheres at about 900°C . The decomposition starts from the boundry of the piece & proceeds inwards the rate of which is directly proportional to the prevailing temperature in the calcination zone, heat travelling from outside the piece to inside under the influence of temperature gradient. The decomposition takes place in a very narrow zone i.e. the phase boundary-between CaCO_3 & CaO which means that the temperature of the outer surface will have to be maintained higher than inner cone to facilitate flow of heat & the velocity of the decomposition will be directly proportional to this difference temperatures. Further, free liberation of CaCO_3 from the stone would require its partial pressure to be above one atmosphere which implies that the temperature at the centre of the piece must be slightly higher than 900°C which in turn implies that the temperature of the calcination zone which prevails upon other surface of the piece must be substantially higher than this temperature. However, great care has to be taken to maintain the temperature of the burning zone within the limit which promote good rate of combustion. Maintaining a temperature much higher than required & thus exposing lime to higher temperature results into an atomic rearrangement yielding 'Over-burnt' or 'Dead burnt' lime having 25% higher density than properly calcined lime. It is due to fusion of

the outer surface of the lumps leading to formation of an impermeable layer of blackish mass on the outer surface. Such lumps having very low hydration rate slaks with difficulty & pass unslaked through slaker. Quite often such lumps of 'dead burnt' lime have unburnt stone after the layer of 'over burnt' mass as the outer layer resists passage of CO_2 through it preventing further decomposition of the stone in core. Presence of acidic impurities e.g. SiO_2 , Al_2O_3 & Fe_2O_3 promote this action rapidly while MgCO_3 with its higher calcination rate acts as an agent for such formation.

As for optimum calcination temperature, there is a great diversity of opinions. Cunningham suggests as high temperature as between 1200°C — 1300°C to be maintained for good calcination rate while German literature restricts it between 1050°C to 1100°C only presumably owing to high magnesium content of German-Stone. Hugot gives a wide range of 1100°C to 1300°C for the purpose. In Indian conditions with all considerations of making a compromise between a good combustion rate & preventing over burning, a temperature in the range 1100°C to 1200°C has been found to be quite suitable.

The physical properties of lime stone bear comparatively less significance on the burning process. The stone should be hard enough to withstand the pressure developed in Calcination so as to avoid pulverization and it should be compact with low porosity to facilitate good calcination.

Effect of Impurities :

As has been discussed earlier lime stone is most commonly contaminated with impurities like Silica, Iron & Aluminium Oxides, Magnesium Carbonates, Sulphates & traces of alkali metals. The most objectionable impurities which decide suitability of lime-stone for its use in the lime kiln in sugar factories, are Sulphates, Silica & Magnesium for their deleterious effects during burning process & then after in processing of the juice.

Among these Sulphates affect processing of the cane juice adversely while other impurities hamper a good working of the Kiln it-self. The basic character of Lime permits it to react with acidic impurities like SiO_2 , Al_2O_3 , Fe_2O_3 . Silica together with CaO & Alumina of refractory liming can form Eutectics having low melting points in varying composition. Formation & sticking of silicates obstructs downward descent of the lime stone hindering uniform working of the Kiln. Magnesium Carbonate having higher combustion rate than CaCO_3 tends to formation of 'Over burnt' lime even under normal conditions if not checked carefully & after calcination when it infiltrates with limes, it retards filtration. It is for these reasons that maximum stress has to be laid down on the quality of the stone to contain these impurities as low as possible. Honig has drawn specifications for the quality of Limestone suitable for burning in sugar factories as give in Table No. 2.

Quality Conditions :

Hardcoke used for promoting combustion in lime kiln should bear maximum percentage of ash well below ten. It should not be brittle to crumble into fines while being broken & contain minimum percentage of sulphur which leads to formation of sulphurous acid having corrosive action.

3. Operational Conditions

Operation of lime kiln is highly skilled & requires very delicate & sensitive handling for obtaining best results as conditions vary from time to time & with every consignment of the feed. Any slackness in supervision & regulation of its working may totally upset its working, disrupting process operation as a whole, as it assumes the significance of back-bone for a carbonation sugar factory. Some of the fundamental principles underlying the working of a kiln have already been dealt in the foregoing sections which explain the importance to maintaining proper temperature of decomposition as well as retention time in the combustion zone for individual piece to facilitate the supply of latent heat adequate for decomposition & its total conversion into active lime. Other factors which directly influence lime kiln operations & so require constant vigil for attaining optimum efficiency are discussed here after in-short.

(i) Ratio of Coke to Lime Stone :

Theoretically speaking lime stone requires

425 K. Cal. per Kg. for decomposition & hard coke normally conserves a calorific value of about 7000 K. Cal. per Kg. As such a ratio of coke to lime stone at 1 : 16 : 5 (6 % by weight) should be sufficient. In practice, however, this quantity falls insufficient as heat loss in kiln gases, radiation etc. have to be made up. The practical values vary between 1 : 13 (7.7%) to 1 : 11 (9% by weight) depending upon thermal efficiency of the kiln & operational control. With a modern & well controlled lime kiln a ratio requiring 7.5-8.0 per cent coke by weight can be attained successfully.

(ii) *Size of Lime Stone & Hard Coke Pieces :*

It is another important factor detrimental for efficient & economic working of the lime-kiln. Time of decomposition of limestone is a function of temperature & is directly proportional to the smallest piece in the charge. Decision about of the right size of pieces for burning depends upon the design, individual operating conditions of the kiln & the capacity it has to cater. If greater output is required pieces of smaller size are to be used but there is a limitation in this respect also as very small piece of lime stone will hinder the passage of stock gases. It is due to this practical difficulty that kiln working on fluidised-bed, principle using fine pieces of limestone have been developed in some countries which are highly economical. The usual size of limestone varies from 6 cms. to 12 cms, the larger pieces being ideally suited for burning in tall kilns. Whatever may be the suitable size fixed

for a particular kiln, the pieces conforming to it should be as uniform as possible. Such a stress is laid on the uniformity of the pieces because irregular sizes of limestone has got a potential to produce at the same time both 'Under-burnt' & 'Over-burnt' lime. If there is wide variation in size of the pieces the smallest piece will get calcined at the earliest & in an effort to burn larger pieces it may become 'dead burnt' while the larger piece might still be retaining a core of unburnt stone.

(iii) *Size of hard Coke :*

The size of hard coke suitable for promoting calcination is generally kept just half of the stone size. Here also, uniformity of pieces is essential because irregular size tends to increase the calcination zone.

Uniformity is the essence of an efficient & economical working of the lime kiln at every stage of its' operation right from charging the feed to discharge of lime lumps, preparation of milk of lime & its' ultimate addition to juice. It has been practically observed that some operators have a tendency to disturb uniformity of operations in temptation for getting over some trouble quite frequently but it is a disastrous practice which must be desisted from as gives only tranquillising action & not a complete solution. Many a times it gives jerks & so adversely affect the smooth working of the kiln & sometimes even damage it considerably. For example once the optimum ratio of fuel : lime stone is fixed consistent with the working conditions of the Kiln, it must be continued uniformly, till there is a definite

variation in the quality of the stone. It should not be changed frequently to overcome the problem of 'Over' or 'Under' burnt lime which may be due to several other reasons e.g. irregular size of stone & coke, ununiform mixing of the charge of stone & coke or its' distribution over the entire area of the shaft resulting into all maintenance or shifting of the Calcination zone. Such a problem has to be faced with patience, caution & prudence rather than resorting to short-cut methods which can at the maximum provide short term gains & not the complete solution in regularising the good working of the Kiln.

Similarly frequent change in the speed of CO₂ Pump is highly injurious to working of the Kiln by frequent raising & lowering of the Calcination zone. This needs special attention because carbonation Operators have a definite tendency to increase suction by interfering with the speed of the Pump. Such a practice should never be resorted as it invariably leads to erratic working of the Kiln.

Repair & Maintenance of Lime Kiln :

In off-season, entire lime kiln has to be thoroughly checked & corroded fire-bricks have to be changed which should receive maximum attention. Fire bricks of suitable specifications are to be used & joints should be made with a very thin layer of fire-clay so that joints do not give way while in operation.

Composition of Fire-Bricks :

Beside being exposed to a high temperature, the firebricks forming the lining of the

Kiln are subjected to abrasive & chemical reaction as well as sudden temperature changes also. These should have a composition to withstand shrinkage after cooling with minimum porosity permitted by temperature-changes in the Kiln.

HONIG specifies fireclay bricks containing 30-35% Al₂O₃ & 25% porosity to be most suitable for use while TROMP suggests using firebricks with 41-43 per cent Al₂O₃ content & 48-49% Silicon Oxide content having 16% porosity & expansion coefficient lower than 0.1%.

Practical Considerations : Difficulties & Checks :

A lime kiln meeting the good standards of working yields lime lumps having a temperature of 45-50° C which is light in weight, porous & hydrates easily as interatomic spacings allow easy penetration of water. It should be given sufficient time to slake with pure water, usually condensates from III or IV body of evaporators to avoid any import of impurities with it. It is always advisable to have milk of lime storage tanks fitted with stirrers having a holding capacity of about 8 hours requirement. These tanks, normally two or three in number help in maintaining the desired density of milk of lime & at the same time, their holding capacity helps in dealing with any trouble in the working of the Kiln.

CO₂ Gas :

Its percentage should vary between 35-40% under good operating conditions. If this falls below 30% it should be alarming to a techno-

logist to check all working conditions of the Kiln thoroughly. It may also happen due to dilution with excess air creeping through leakages either in the suction pipe or through poke holes which must be immediately stopped. Any increase in the percentage of Carbon monoxide beyond 1% indicates inadequate draught which should be between 7.5 to 10.0 Cms. vacuum at CO₂ Pump. The temperature of CO₂ Gas as it emerges from the kiln should be 50-70° C which is cooled down in washer & scrubber to 45-50° C.

Jamming & Scaffolding :

If Kiln operations are handled countiously such problems should never arise but owing to some reason or the other jamming or arch formation occurs. It should be removed by mechanical breaking. Tempted by quick results, some operators resort to break them by slaking through water nozzles in the Kiln itself which is very hazardous & invariable leads to serious damage to lining of the Kiln, especially when it happens to be in combustion zone it may follow explosive consequences & hence this practice must always be avoided.

Country Kiln :

It is always advisable to keep one country kiln as a supporting source for facing the trouble & giving adequate 'rest' to the kiln when needed. It ensures economy also as it burns smaller pieces of stone unsuitable for main kiln & unburnt pieces of stone leaving nothing to be wasted. The lime produced by it may be stored in a godown & kept in readiness for meeting any difficult situation. This should however, be never encouraged as a permanent source of extra requirements.

While operating it care should be taken that lime is not pulverised before storage.

Conclusion :

Almost every aspect touching the lime kiln operations has been discussed. While the Factories having plans for expansion should go for modern cylindrical kilns equipped with mechanical charging & discharging devices, suitable modifications may also be done in existing kilns, where ever possible. Due emphasis has to be given to equip this station with proper instrumentation like gauges, recorders, Pyrometer etc. which is found to be neglected in many factories due to which technical & precise control of this important station is not possible which ultimately leads to inefficient & uneconomic working. Quality of lime stone & hard-coke have to be checked & even if desired CaCO₃ content is not always available, atleast objectionable impurities have to be avoided. As this station still involves a lot of human-factor constant alert & supervision has to be maintained for obtaining best results.

Lime kiln is one of the most labour intensive stations in Carbonation Factories & in many cases it is more than required for normal operations. Un-wanted strength can be reduced effectively by striking a systematic working sequence at every stage in the existing conditions while it can be substantially reduced by incorporating modern devices of automatic feeding & discharging where ever possible which will improve the efficiency also. Certain can qualities demand addition of more lime for complete clarification but in any case when lime stone consumption exceeds 4.0% cane, it warrants immediate concern for regulating the

working at high levels of efficiency by strict supervision which alone can reduce the consumption in turor can ensure economical working of the station.

Acknowledgement :

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Table—1
Removal of Non-Sugars by Different Processes

Process	Defecation	Sulphitation	Carbonation
Removal of Non-Sugars (%) in Mixed Juice.	12.7	11.7	27.9

Table 2
Standard Specifications of Lime Stone Suitable For Fime-Kiln
In a Carbonation Sugar Factory

S. No	Particulars	Desired Percentage
1.	Solids insoluble in HCL	1 Per cent (Maximum)
2.	Silica (Si O_2)	1 Per cent (Maximum)
3.	Iron & Aluminium Oxide	1 Per cent (Maximum)
4.	Magnesium Oxide	1 Per cent (Maximum)
5.	Sulphates	0.1 „ (Maximum)
6.	Calcium Carbonate	95 „ (Minimum)

OLD BRICK WORK SHAFT
LIME KILN

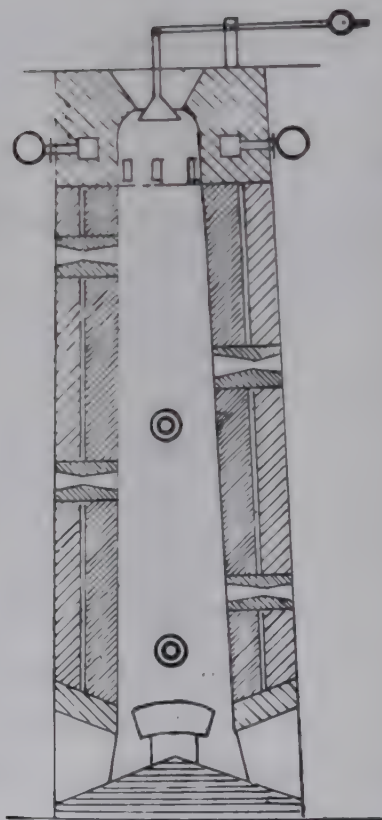
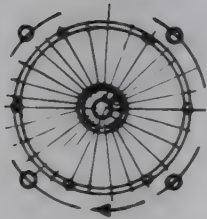
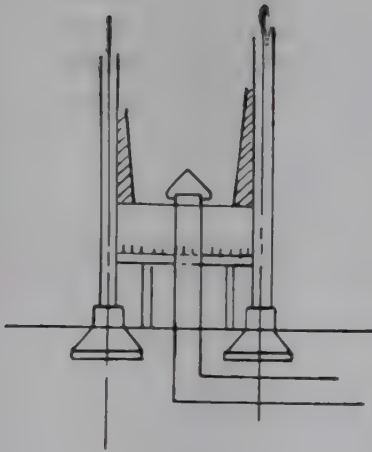


Fig. 1

KHERN OR BELGIAN
LIME KILN

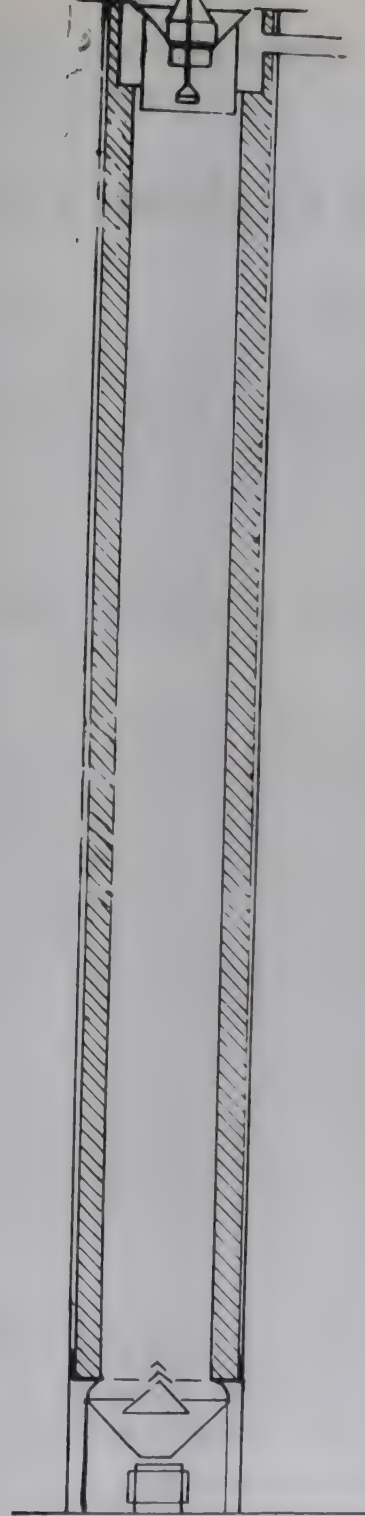


Fig. 2



CIRCULAR SHIFT BAR GRATE
FOR BELGIAN KILN

Fig. 2a



MODERN LIME KILN WITH
ROTARY GRATE & GRASS
HOPPER CONVEYER

Fig. 3

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NEED FOR A PROPER FORMULA FOR REDUCED MILL EXTRACTION

By

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ABSTRACT

At present mill extraction of a milling tandem is calculated by Noel Deerr's formula called 'Reduced Mill Extraction which postulates to reduce the mill extraction to a common fibre of 12.5% on cane. But this figure has been found to be effected by fibre % and favours higher fibre and higher pol % cane. So a modified form the formula given by Hugot has been suggested to give Reduced Mill Extraction at a common fibre of 12.5% on cane and at a common sucrose of 12.5% on cane, taking into consideration the length of milling tandem, which also has an accepted influence on milling efficiency.

Introduction

In India at present about 270 sugar factories are working and about 80 sugar factories which have been issued letters of intent are also about to come up. The authors during their advisory tours to the factories while taking 'Performance Trails' of new sugar factories came across two cases where Pol % Cane was too low. The agreements usually provide the following —

"The sugar plant shall be capable of crushing per 22 working hours 1250 tonnes of sugar cane with a fibre content of approx. 12 to 15 per cent and a minimum sucrose content of 12.5 per cent to produce commercial white sugar and the milling plant give an average extraction of not less than 93 per cent on sugar cane with a fibre content of 12.5 per cent while applying maceration upto 180% on fibre. The capacity and efficiency of the plant shall

be deemed to have been fulfilled even after one month from the start of crushing operation and the boiling house being in normal working condition on any three consecutive days, an average of 1250 tonnes of sugar cane with a fibre content of approx 12 to 15 per cent are crushed in 22 working hours and on 5 consecutive days provided milling plant gives an average extraction of 93% based on sugar cane with a fibre content of 12.5% and a minimum sucrose content of 12.5 while apply-

ing maceration water up to 180% on fibre."

The efficiency part of mills have always been a source of contention.

For assessing the efficiency of a milling tandem and its comparison with other sugar factories in India and abroad, the internationally accepted formula termed as 'Noel Deerr's Reduced Mill Extraction' given below is used :

$$\text{R. M. E.} = e_{12.5} = \frac{7 - V}{7} \quad \dots \quad \dots \quad \dots \quad (1)$$

$$\text{Where } V = \frac{(1 - e)(1 - f)}{f}$$

e = mill extraction

f = fibre — cane

This formula postulates to reduce the extraction to 12.5% fibre. Actually the reduced mill extraction calculated by Deerr's formula is effected^{2,3} by fibre % cane and higher the fibre than 12.5%, the higher² will be R. M. E. (Deerr). Not only this, it is effected by sucrose % cane also and higher sucrose content in cane registers a higher R. M. E. and with lower sucrose content, the R. M. E. is depressed. The discrepancies observed by us in three cases are placed below :

Case No. I

In the case of a new factory in Haryana having a 12 roller tandem, the following figures were obtained during 5 days of trial. Here the Pol % cane was lower than 12.5% :

	1st day	2nd day	3rd day	4th day	5th day
1. Cane crushed (Tonnes)	12.20	11.20	12.40	11.80	11.00
2. Fibre % cane	15.32	13.50	14.28	14.50	14.32

Contd.

	1st day	2nd day	3rd day	4th day	5th day
3. Added water % cane	21.41	22.72	21.14	22.87	25.36
4. M. J. % cane	86.99	91.83	89.38	60.59	93.62
5. Pol % cane	10.78	10.68	10.76	10.74	11.24
6. Pol % bagasse	3.13	3.22	3.00	3.28	3.34
7. Bag % cane	34.18	30.63	31.49	32.08	31.70
8. Pol % M. J.	11.16	10.56	10.99	10.70	10.88
9. Pol in M. J. % cane	9.71	9.697	9.82	9.688	10.18
10. Mill extraction	90.07	90.77	91.26	91.76	90.57
11. Red. Mill extraction Deerr's at 12.5 % fibre	92.10	91.55	92.43	91.76	91.96

Thus the Reduced Mill Extraction by Deerr's formula was much below the guaranteed performance, but pol % cane was also much lower.

Case II.

Let us see another case in extreme east of India, in a factory in Assam, having a 12 roller tandem. Here also the Pol % Cane was low. The working figures for a season were given below :

1. Pol % cane	8.27
2. M. J. % cane	89.82
3. Pol % Mixed juice	7.94
4. Pol in M. J. % cane	7.13
5. Fibre % cane	14.78
6. Imbibition % cane	23.27

Contd.

7. Pol % bagasse	3.41
8. Bag. % cane	93.32
9. Pol in Bag. % cane	1.14
10. Mill extraction	86.26
11. Red. Mill Extraction (Deerr's)	88.86

This reduced mill extraction recorded by Deerr's formula is definitely too low :

Case III.

In one factory in Maharashtra having a 12 roller tandem, the figures noted were :

1. Pol % cane	12.90
2. Fibre % cane	14.06
3. M. J. % cane	86.74
4. Added water % cane	17.74
5. Bagasse % cane	30.66
6. Pol % bagasse	3.22
7. Pol in bagasse % cane	0.99
8. Pol in M. J. % cane	11.91
9. Mill Extraction	92.36
10. Red. Mill Extraction (Deerr)	93.15

In this case, the R. M. E. has marginally crossed the standard of 93.0 extraction but the Pol % cane was 12.90.

As seen in Case I and II, when the R. M. E. goes below 93.00, the situation becomes very difficult and immediately the calculation of R. M. E. by Deerr's formula was questioned. India is a vast country and Pol % cane varies widely from 9 to 16.0 per cent in cane and efficiency figures have to be calculated to satisfy the parties.

Other Formulae for Mill Extraction

Recently some formulae have been suggested :

(1) Milling loss

This is usually used in Hawaii, taking into account the sucrose / fibre coefficient, taking into account the moisture content of bagasse and is given as :

$$\text{Mill Loss} = \frac{\text{Sucrose (or Pol) in bag. \% cane}}{\text{fibre \% bagasse}} \dots \dots \dots (2)$$

This formulae however, does not correct for sucrose % cane and would not suit conditions in India.

(2) Extraction Ratio

This also is a formula brought into prominence by Hawaiian Sugar Industry. The expression used is :

$$\text{Extraction Ratio} = \frac{100 (100 - \text{Extraction})}{\text{Fibre \% cane}} \dots \dots \dots (3)$$

This expression corrects for fibre % cane and also sucrose % cane, as it considers extraction and can be a suitable basis for comparison but does not reduce the figures to any fixed fibre % or Pol % cane and would not serve our purpose.

(3) Mittal's whole Reduced Extraction (w. r. e.)⁵

Mittal has tried to give an expression w. r. e. for comparison of milling efficiency by reducing the fibre to 12.5% and sucrose or Pol at 12.5%. The expression reads

$$\text{W. r. e. (Mittal)} = 1 - \frac{\text{Pbc}}{f} \dots \dots \dots (4)$$

Where Pbc = Pol in begasse % cane

f = fibre % cane

(4) Hugot's Reduced Extration⁶

He has put forth his own formula having a compromise between the two schools of thoughts represented on the one hand by the milling loss (no influence of sucrose increase) and on the other hand by the extraction coefficient (proportional influence of sugar content).

$$\text{Reduced Extraction (Hugot)} = \frac{\sigma}{f'} \frac{1.657}{N\sqrt{R}} \quad \dots \quad (5)$$

Where

$$\begin{aligned} \sigma &= \text{Pol \% bagasse} \\ f' &= \text{Fibre \% bagasse} \\ R &= \text{Pol \% cane} \\ N &= \text{No. of mills in a tandem} \end{aligned}$$

assuming a standard tandem of 5 mills and at a pol % of 12.5. He has put it as a compromise between Deerr's expression and Mittal's formula for reduced mill extraction. According to him 'all the formulae are based on the hypothesis that other things being equal the sugar lost in bagasse is proportional to the sugar content of cane.' He has also referred to a school of thought which considers that the sugar lost in bagasse does not depend on sugar content of cane but he accepts the effect of number of mills and pol % cane on the extraction figure alright while giving an expression of reduced mill extraction.

The authors are of the view that number of mills in a tandem and sucrose content in cane both effect extraction with other things remaining common. Imbibition is also more effective as number of mills in a tandem goes to 21. Hugot has tried to take for granted a 15 roller tandem and has given the constant in his equation. When the number of mills are 4, it would not be correct to assume that these are five mills, similarly if a tandem has 18 or 21 rollers, we cannot assume it to be 15 roller tandem and as such the constant 1.657 should not be used. It is, therefore, suggested that a general formula should be accepted compensating the efficiency of a tandem; the formula would then be :

$$\text{Reduced Extraction (Bhargava)} = 100 \left(1 - \frac{\sigma}{f'} N \sqrt{\frac{12.5}{R}} \right) \quad \dots \quad (6)$$

Where

$$\begin{aligned} \sigma &= \text{Pol \% bagasse} \\ f' &= \text{Fibre \% bagasse} \\ N &= \text{No. of mills in a tandem, taken 3 roller mills as one mill} \\ R &= \text{Pol \% cane} \end{aligned}$$

If the numerator and denominator are multiplied by bagasse % cane, the formula (6) can be further written as

$$\text{Reduced Mill Extraction (Bhargava)} = 100 \left(1 - \frac{Pbc}{f} N \sqrt{\frac{12.5}{R}} \right) \quad \dots \quad (7)$$

where $\frac{Pbc}{f} = \text{Pol in bagasse \% cane}$
 $\frac{f}{f} = \text{fibre \% cane}$

This formula is more or less the same as Mittal's except that a factor $N \sqrt{\frac{12.5}{R}}$ has been introduced to compensate for the effect of number of mills and Pol % cane. The authors do feel that number of mills in a tandem should not be a consideration while finding out the efficiency of a milling tandem but it is a fact that the length of a tandem not only adds to the crushing capacity but also improves extraction and as such while reducing the efficiency figures weight age should be given to the length of the tandem.

Discussions

Applying the Mittal's, whole reduced extraction and Hugot's modified formula by authors No. (7) to the above three cases, the figures give the following Reduced Extraction at a reduced pol and fibre of 12.5 % respectively.

	R. M. E. (Deerr's)	w. r. e. (Mistal)	Reduced Extraction (Bhargava)
Case I			
1st day	92.10	93.02	92.75
2nd day	91.55	92.69	92.40
3rd day	92.43	93.38	93.13
4th day	91.76	92.74	92.46
5th day	91.96	92.61	92.41
Case II	88.68	92.70	91.46
Case III	93.15	92.96	93.01

It can be easily seen from the above data that in case I, according to Deerr's formula, the milling efficiency had been much below 93.0 extraction, just because of lower pol % cane. When Mittals w. r. e. was applied, no 1st and 3rd day the performance was above 93.0% and even on other days although it was slightly below but not too poor. By Modified formula (Bhargava) efficiency was

above 93.0 on one day but on other days it was much better than given by Deerr.

In case II, when Deerr formula gave a figure of 88.68 which is shocking too low, Mittal's w. r. e. was 92.7 and by author's formula it was 91.46. This factory, it may be mentioned, had good setting but due to improper control of speed of cane carrier feeding and preparation had become poor.

In case III where Pol % cane is higher than 12.5 the Deerr's formula gives a R. M. E. of 93.15 but when reduced to 12.5 fibre and 12.5% pol by Mittals w. r. e. and equation No. (7), the figure are 92.96 and 93.015 respectively. Had the pol % cane been higher, the difference would have been much higher in reduced figure. Due to this formula R. M. E. calculated is too high when pol % cane is higher and thus the figure become misleading. This aspect is more pronounced where fibre % cane is high. It is thus observed that Deerr R. M. E. formula does not provide standard for comparison of milling efficiency or judging the efficiency of a milling tandem. While accepting a reduced figure for milling efficiency it should be reduced to a constant

fibre of 12.5% cane and also to a pol % cane of 12.5 and should calculate it as given in equation (7). There is an immediate need for acceptance of either of the two formulae given above for India pending acceptance by ICUMSA and other countries and we should discard calculation of Reduced Mill Extraction by Deerr's formula, the discrepancy in which has been amply proved during the last two decades.

Acknowledgment

We are very grateful to Dr. N. A. Ramaiah, Director, National Sugar Institute, Kanpur for the encouragement given to us in carrying out the work.

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Chemical control & Analysis Section



PART I SPECTROPHOTOMETRIC METHOD OF DETERMINATION OF SUGAR IN TRACES

By

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ABSTRACT

A method of determination of low concentration of total sugar 100 ppm has been studied on the principle that solution of Molisch's test (α -naphthol test) gives an absorption maxima at 570 m μ on Beckman spectrophotometers. Sugar samples like AR sucrose, E-30 and E-29 show good response and Beer's Law is obeyed upto approximately 100 ppm. Sugar contained in condensate water and injection water show satisfactory results.

Introduction

In Sugar industries the knowledge of concentration of sucrose at various manufacturing stages is necessary and it is usually estimated by four different methods¹, these include polarimetry², refractometry³, reduction method⁴ and densitometry⁵. In polarimetry, the optical activity of sucrose originating due to the presence of asymmetric carbon atoms in the molecule is utilised to determine its concentration. In refractometry, the change in refractive index of a given solution accounts for the concentration of sucrose. In

reduction method, on the other hand, the reducing action of inverted sucrose is utilised in which the reduction of cupric ions to cuprous state is estimated quantitatively by employing various techniques and that enables the back estimation of sucrose. In densitometric method, sucrose is estimated as a dissolved solid by Brix spindle. Though all these methods, are satisfactory and simple but their accuracy is limited only to the per cent concentration and for ppm range they are inadequate. It was therefore, thought to investigate a method which could estimate the concentration of sucrose upto 100 ppm.

Principle of the method

For the present method the well known Molisch's test⁶ which is used to determine the presence of sugar qualitatively, is utilised. In this test, sugar solution in presence of α -naphthal (4% alcoholic) and conc.-H₂ SO₄ gives a violet ring at the junction of two liquids. The entire reaction mixture upon cooling and shaking becomes homogeneous and gives absorption maxima at 570 m μ on Beckman spectrophotometers, as shown in Figure 1. The optical density of solution at this wavelength depends upon the concentration of sucrose and this forms the basis of spectrophotometric method of determination of sugar.

Experimental

To a mixture of 5.0 ml of AR sucrose solution (known concentration) and 0.10 ml α -naphthal, 4.90 ml of conc. H₂ SO₄ was added slowly so as to get deep violet ring. The reaction mixture was then cooled under tap water and the solution was made homogeneous which is distinctly purple. The optical density of such solution was determined at 570 m μ on Beckman Model B and DU and measurements were repeated with variable sugar concentration upto about 150 ppm. Tests were made to check up the reproducibility with different samples and were found to be within 1% error. In addition two types of commercial sugars like E-30 and E-29 were tried in analogous manner. In order to extend the applicability of the method condensate water, effluent water and injection water were also tried. For condensate water filtration was not necessary but other

liquid samples were filtered using whatman filter paper No. 1. Except for condensate water liquid samples were twice diluted before use in order to observe optical density reading on the scale, since upto 100 ppm sucrose concentration, no dilution was required. The optical density of blank solution made of α -naphthal and conc -H₂ SO₄ and water was determined and it was found satisfactory to be subtracted from the observed optical density to obtain the Beer's plot for each sample.

Results and Discussions

Sucrose Samples :

The results of AR sucrose and commercial sugar, and E-30 are quite overlapping. The Beer's Law in case of AR sucrose is obeyed upto 100 ppm but in case of commercial sugars like E-30 and E-29 its validity is only upto 10 ppm and 80 ppm respectively. These curves of AR sucrose and E-30 have been shown in Figure 2 and that of E-29 in Fig. 3. It is noticed from the slope of Fig. 2, that one ppm of AR sucrose amounts to a change of 0.009 units in optical density. In case of E-29 one ppm of sugar corresponds to a change of 0.0085 units in optical density. Thus if the experiment is performed carefully then even one ppm of sugar can be well estimated since the change of 0.005 unit in O. D. may be satisfactorily estimated by Beckman spectrophotometer provided the test solution is fairly colourless.

Calculation of concentration of sucrose from optical density measurement at 570 m μ for AR sucrose is illustrated as follows ;

$$\text{Concentration (ppm)} = \frac{\text{observed O.D.} - x}{y} \dots 1$$

Where $x = 0.65$ and $y = 0.0095$. Thus is the observed O. D. without subtracting the blank reading is 1.10 for a given solution of AR sucrose, then the concentration of sucrose turns out to be about 47 ppm. The equation (1) holds good for any sugar sample with a slight shift in the values of x and y . The average values of the two constants that x and y can be satisfactorily taken as 0.65 ± 0.05 and 0.009 ± 0.005 respectively for almost all commercial sugars with a shift in accuracy of ± 5 ppm. Thus depending upon the nature of accuracy required for the sugar analysis these constants can be accordingly taken to estimate the actual concentration of sucrose in a given sample. Incidentally, one should note that the value of x is the optical density of blank solution.

The concentration of total sugar estimated by this method in condensate, injection and and effluent water were found to be 50 ppm 100 ppm and 90 ppm respectively.

Glucose and Fructose Samples

In order to observe the affect of inversion in the system, A. R. samples of glucose and fructose were tried separately. In case of fructose the colour identical to that of sucrose was obtained where as no clear violet ring was observed with glucose and correspondingly only fructose gives clear absorption maxima

but at $550 \text{ m}\mu$. This maxima has been shown in Fig. No. 4. The optical density data of glucose though gave an indication of maxima at $552 \text{ m}\mu$ but it was not distinct.

It is expected that the presence of conc. H_2SO_4 may cause inversion of sucrose and some interference due to the presence of glucose and fructose could be experienced. But the fact that absorption maxima of sucrose differs from fructose and sucrose by $20 \text{ m}\mu$, its absorption maxima at 570 may be taken as a criterion for sucrose. Though all carbohydrates give violet colouration but they should be distinguishable in absorption maxima.

Applications

In Sugar analysis where low concentration of Sugar cannot be estimated quantitatively, this method may be readily applied. Thus this method can be satisfactorily adopted for the quantitative estimation of sugar in condensate water, injection water and effluent water etc. As an extension this can also be applied to estimate the unknown sugar losses quantitatively. In spite of its great promises to estimate quantitatively the traces of sugar it suffers with an obvious limitation that it determines the total sugar and not exclusively sucrose.

Acknowledgements

We are thankful to Dr. N. A. Ramaiah, Director, National Sugar Institute, Kanpur and to Dr. S. K. D. Agarwal for their interest in the work.

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BEERS PLOT OF AR SUCROSE AND E-30 SUGAR

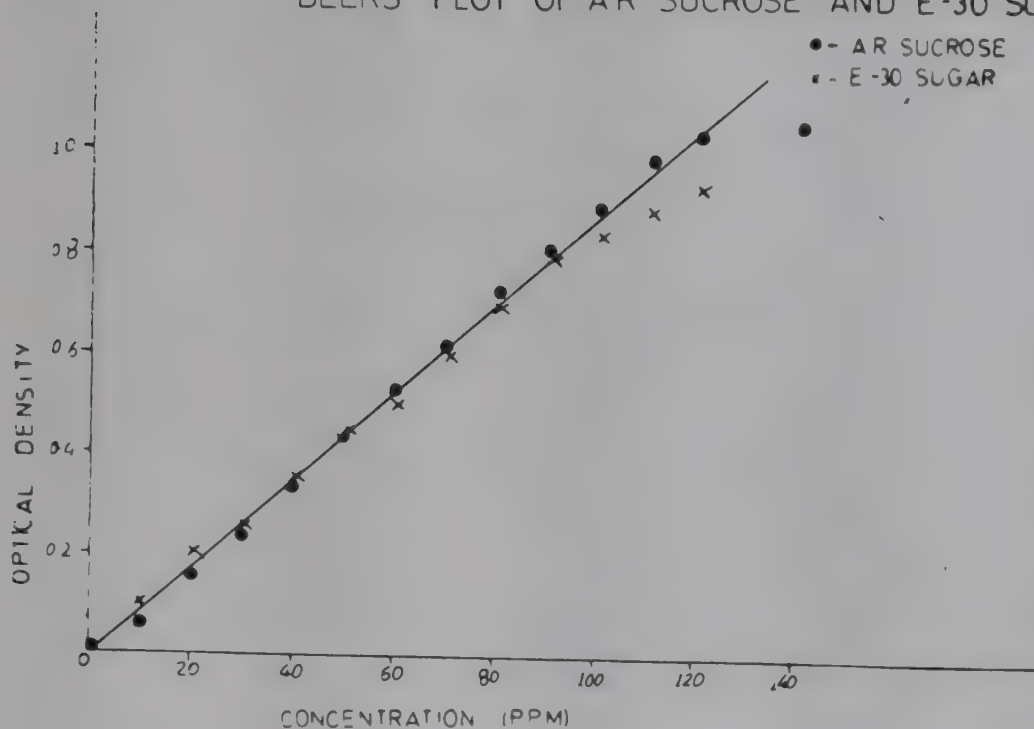


FIG 2

ABSORPTION MAXIMA OF AR SUCROSE

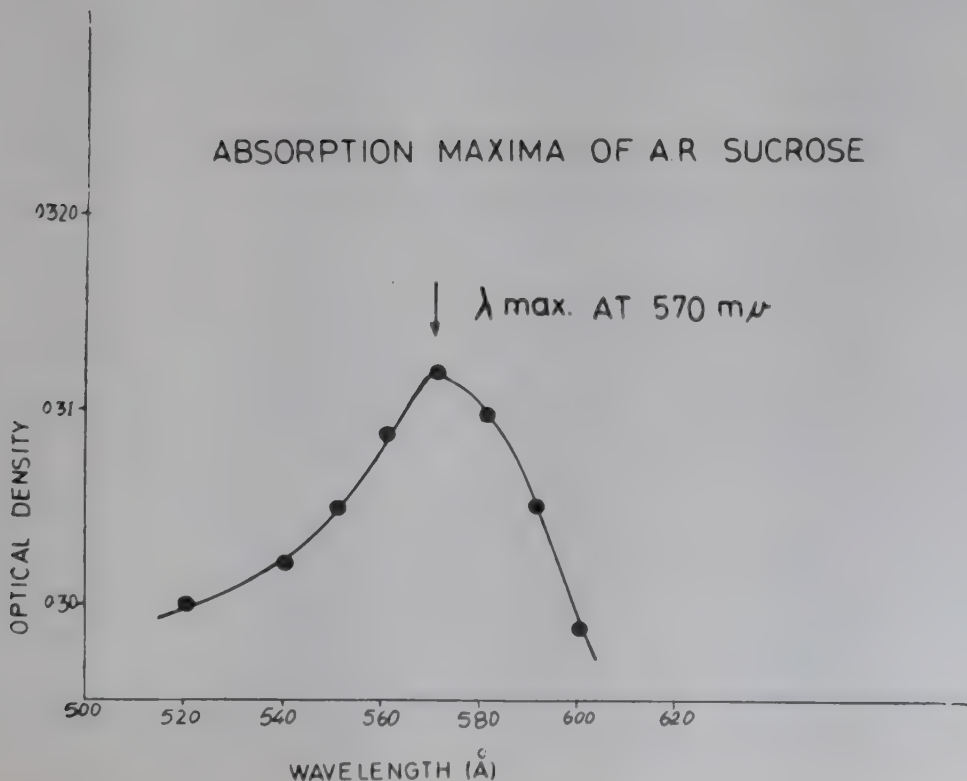


FIG 1

BEER'S PLOT OF E-29 SUGAR

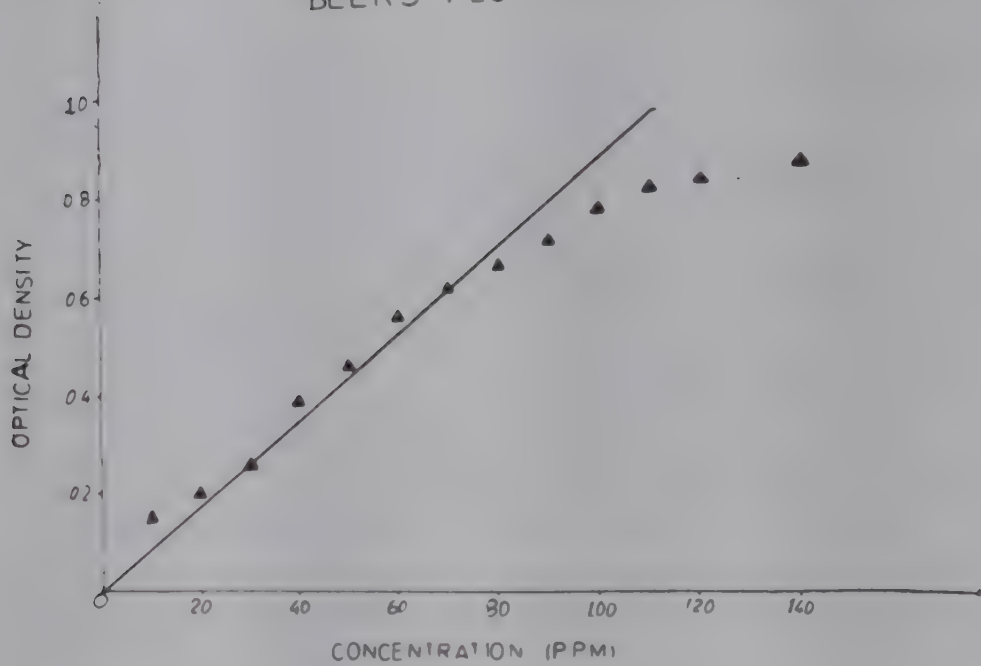


FIG 3

ABSORPTION MAXIMA OF A R FRUCTOSE

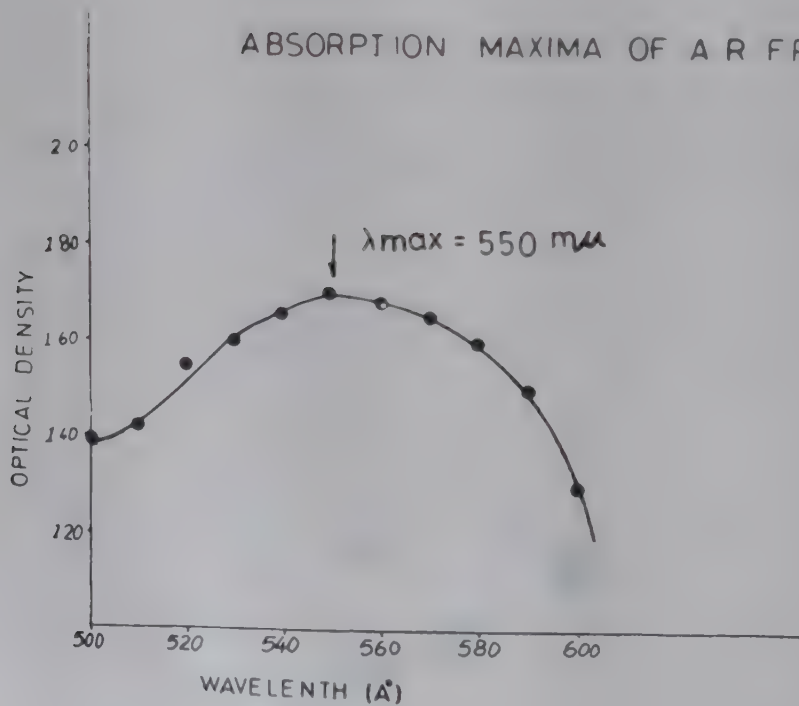


FIG.4

ABNORMAL BEHAVIOUR OF BOILER WATER

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ABSTRACT

Boiler Water Treatment with alkali shows down fall in pH instead of rise in pH. This abnormal behaviour of Boiler Water is attributed to formation of methylglyoxal, which is an unstable compound and on alkanisation polymerises to show this downfall in pH. Indirectly it is suspected that vapourcell where high pressure and temp is maintained destroys Reducing Sugars to form this compound. Remedy for this is precipitation of aldehydes by addition of bisulphites.

Introduction :

About 3 years back, Kolhapur Cane Sugar Works experienced a peculiar phenomenon on the Boilers. Boiler feed water, on treatment with alkali and usual dose of Alflock powder, supplied by I. C. I., showed reduction in pH; instead of showing rise in pH. That time, a search was made to find out the reason for the same by analysing boiler feed water, Boiler water and the condensate. Next year Shahada factory experienced the same. Then came the turn of Ugar, Datta etc. and this year Bhogawati factory also came across the same problem.

Previously it was thought that this peculiar behaviour was restricted to particular region for particular time. Many speculations were made. But now, slowly it is experienced that this abnormal behaviour of Boiler Feed Water is becoming a permanent feature with most of the factories. It is observed that every factory which experienced this, had a vapour cell and upto now, no factory without a vapourcell has come across this problem.

At the request of the Chief Engineer, Bhogawati, the authors had an occasion to visit the factory during this trouble when a search was made to find out the reason and to

overcome the difficulty and the difficulty was overcome.

The Facts of the case

Usually Boiler Feed Water received from the pan, evaporator and juice heater condensate has got 6.5 to 7.5 pH. Normally on alkali addition the pH rises to 9 or beyond 9, upto 11 and it remains so for a pretty long time so that usually Boiler Water pH is in the vicinity of 11. During this abnormal behaviour, it is found that this pH of Boiler Water comes down upto 3.

P. Honig says that when a solution of Reducing sugars at elevated temperatures is subjected to a ρOH under 5, one of the decomposition products is methylglyoxal (or pyruvic aldehyde, CH_3COCHO) which is a volatile product (boiling point 72°C) which can be detected occasionally, in cane sugar mills in the condensates of evaporators by a positive iodoform reaction. This decomposition product is very unstable and is easily oxidised by O_2 in the condensate and polymirises on alkalization of boiler feed waters. Further when a sugar solution is concentrated in an alkaline reaction at a high temperature, with a pH under 5, it is found in cane sugar mills that the condensates give a positive chloroform reaction thus indicating the presence of methylglyoxal one of the degradation products of hexoses.

Suspecting the presence of methylglyoxal as stated above, both the iodoform and chloroform reactions were conducted with Pan condensates of Bhogawati Sugar Factory. The methylglyoxal indication was determined by the following procedure.

METHYLGLOXAL OR PYRUVIC ALDEHYDE (CH_3COCHO)

Methoxyl No :

The amount of Methoxyl, a chemical radical CH_3O which occurs as a substituent group in some substances and can be determined as methyl iodide by treating the substance with hydroiodide acid.

Determination of Methoxyl No : (See the diagram)

Fill scrubber half way with NaOAc and till receiver 2 fill with freshly prepared KOAc Br solution weigh the sample in platinum boat to required capacity 3 ml. and $\text{Na}_2\text{S}_2\text{O}_3$ soln. and place in bottom of the boiling flask. Add 2.5 ml. melted phenol from wide tip pipette and 5 ml. of HI and connect boiling flask. Pass CO_2 through apparatus from side arm of flask at uniform rate of 15 ml/min. with mentled microburner. Boil the liquid such that vapours rise in condenser but not more than half way. Continue boiling for 60 minutes (for 30 minutes with water with condenser and next 30 minutes without water in condenser) Disconnect flask. Remove the receiver and rinse delivery tubes and contents of receiver into 125 ml. erlenmeyer containing 5 ml. of NaOAc soln. Adjust volume to capacity 50 ml. and add formic acid dropwise until Bromine is destroyed.

Remove any Br vapours by blowing air over liquid then add 0.59 ml. of KI and 5 ml. 10 % H_2SO_4 stir the soln. to dissolve KI and mix contents then titrate liberated I_2 with $\text{Na}_2\text{S}_2\text{O}_3$ using starch as indicator. Determine blank on all reagents making determination

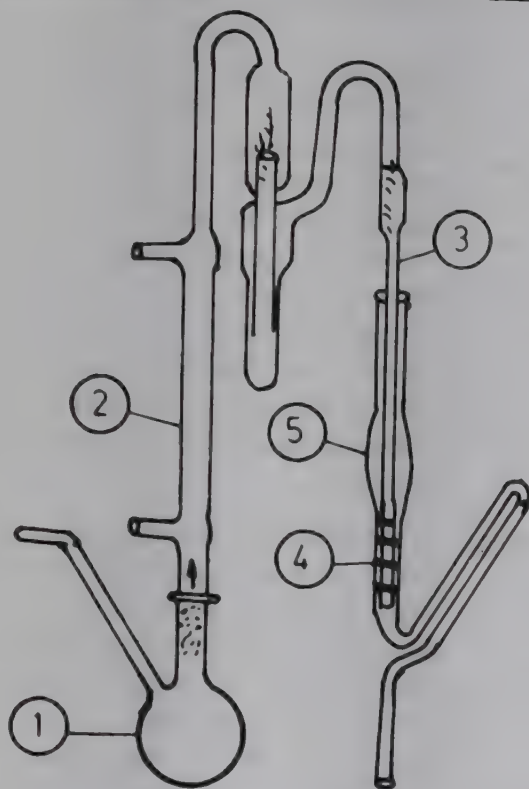
without sample and calculate % of alkoxyl group as follows :

(ml. in detn. - ml. in Blank) x Normality x equal wt.

(x 100/sample wt. in mg.) = %Alkoxyl group

Equivalent wt. Methoxyl = 5.17

ethoxyl = 7.51



- 1 FLASK (Cap 30 ml)
- 2 CONDENSER WITH SCRUBBER
- 3 INLET TUBE
- 4 SPIRAL VOLUMETRIC
- 5 RECEIVER VOLUMETRIC

MODIFIED CLARK APPARATUS

Any standard book in Organic Chemistry States the methods of precipitation of aldehydes as follows :—

- (1) By combining the aldehydes with Bisulphites.
- (2) By precepitation with solid Ammonium Chlorides.
- (3) By addition of Hydrocyanic Acid.

It will be always safer and better to choose. Sodium Bisulphite which is harmless chemical and has got the virtue of having good keeping quality.

On the merit of the above facts, following trials were conducted with the Pan Condensate, Boiler Feed Water and Boiler Water of Bhogawati Sugar Mills, Kolhapur.

(1) In Bhogawati Sugar Factory, all the exhaust steam is given to the vapourcell and the 1st body of the evaporator and all the pans are run on the vapour bled from the vapourcell. Formation of methylglyoxal was suspected in the vapours of the vapourcell, where high temp. was maintained, the steam pressure being 10 lbs/in². Hence condensate from the Pans which might have been contaminated by methylglyoxal formation were tested. Suspecting that this formation might take place in the 1st body of evaporator also, the evaporator which was running for more than a fortnight was taken out of circuit and a freshly cleaned set was introduced.

(2) Addition of Alflock Powder, which was unable to yield any results was stopped.

(3) A combination of 50% caustic soda and 50% Bisulphite was tried on a Laboratory Scale.

(4) Dissolved oxygen content of this condensate was found and was compared with the condensate of Kolhapur Sugar Mills, which was not experiencing this abnormal behaviour. It was found that the D. O. content of this water was 8 times higher than ordinary condensate.

(5) Laboratory trials were conducted both with the condensates of Bhogawati Sugar Mills which was experiencing the trouble and Kolhapur Cane Sugar Works which showed

normal behaviour towards the condensate. The results obtained were as follows :—

According to theoretical conceptions of pH (the total of H and OH ions) concentration comes to 14, pH 11 means pOH 3 and pH 11 means pOH 11. In this particular case, the pH instead of remaining as 11, is covered to 5 pH. This means that the OH concentration is being reduced which culminates into having more of H concentration. It is suspected that the polymerisation of the CHO group from the aldehydes may be reducing the concentration of the OH groups resulting in consequently increasing the percentage of H ions. This again speaks for the formation of methylglyoxal.

In light of these facts, it can be concluded that too much pressure in the vapourcell must be bringing about destruction of Reducing Sugars, with the formation of aldehydes which might be polymerising to exhibit this phenomenon everywhere. So as to feed the Pans only vapours, the vapourcell is always kept under high pressure without caring for the Reducing sugar contents of the juices the vapourcell and repetition of this phenomenon might bring us to rethinking on the use and performance of vapourcell.

Acknowledgements

We hereby thank the Management of Bhogawati Sugar Mills and Kolhapur Cane Sugar Works for providing the necessary samples and the Principal, Polytechnic for allowing us to conduct this work.

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P. Honig—Part I

Official Methods of Analysis AOAC

Organic Chemistry—Finar.

Kolhapur Sugar Mills, Kolhapur **Bhogawati Sugar Factory, Parite**

1st Set	Condensate untreated ρ H	Treated ρ H		Untreated ρ H	Treated ρ H	
		A only Cau- stic Soda 10 ppm.	after boiling		A only caus- tic soda 10 ppm.	B after boiling Soda Sodium bisulphate 10 ppm.
1st Set	6.75	9.15	9.1	9.1	9.05	8.85
2nd Set	6.80	9.2	9.1	9.1	9.0	8.6
3rd Set	6.9	9.1	9.0	9.0	9.0	8.8
4th Set	6.85	9.1	8.89	9.1	9.0	8.8
5th Set	6.8	9.1	9.0	9.1	9.0	8.7
1st Set					9.0	8.3
2nd Set					8.9	8.1
3rd Set					9.2	8.5
4th Set					9.2	8.4
5th Set					9.0	8.2
						9.1
						9.1
						9.1
						9.15
						9.0

General and By-Products Section

WORKING OF POTASH FERTILISER PLANT AT WALCHAND-NAGAR, UTILISING DISTILLERY EFFLUENT

By

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ABSTRACT

After completing pilot trial, the Plant for production of Potash Fertiliser from Distillery Spent Wash, has been converted to Commercial Unit and working continuously to solve the problem of water and air pollution. A Multiple Effect Evaporator is used for concentration of neutralised spent wash concentrated spent wash is dried on the rotary drum drier. Concentrated product contains about 7% potash which is a valuable fertiliser and being imported. Details of the process and the equipment are given. Economic study shows profitability, fully satisfying the main object to conform Water Pollution Act.

Introduction

Liquid Waste of distillery, known as Spent Wash is creating highly polluting load, having 40,000 or more B.O.D. ppm. It is found that it contains some of the valuable chemicals such as Potash, Phosphates and Nitrogen in dissolved condition. This work is concerned with the manufacture of Potash-Fertiliser from distillery waste or other effluents, containing more than 0.7% of potash; more particularly though not exclusively, it is concerned with the manufacture of potash fertiliser from the spent wash of a distillery, distillery waste received directly therefrom and/or effluent

from a methane gas plant after the waste has been subjected to unaerobic digestion in closed vessels for recovery of methane gas. The daily production of spent wash alone is estimated to be around twenty million litres and disposal of such volume of effluents responsible for pollution of air and perennial water has posed a serious problem for industry. Known methods such as bacteriological treatment or solar evaporation and dilution many times prior to disposal, have not provided an acceptable solution.

An object of the endeavour is to provide a process for treating distillery spent wash or

other effluents containing at least 0.7% potash imported commodity, and simultaneously for the recovery of potash, which is now an solve pollution problems.

Process

The process is based on the the following observations :

- (i) that the spent wash from distillery waste has the following composition :

pH.	...	4.20 — 5.00
Brix	...	8.50 — 10.50
Reducing sugars %	...	1.00 — 1.20
Sulphated Ash %	...	3.00 — 4.00
Dry matter %	...	9.00 — 11.00
Carbonated Ash %	...	3.00 — 3.50
Silica (SiO_2) %	...	0.10 — 0.15
R_2O_3 ($\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$) %	...	0.04 — 0.05
CaO %	...	0.20 — 0.50
MgO %	...	0.30 — 0.40
P_2O_5 %	...	0.02 — 0.03
K_2O %	...	0.70 — 1.20
N %	...	0.12 — 0.20
SO_4 %	...	0.80 — 0.85
Carbon %	...	30.00 — 34.00
Hydrogen %	...	2.50 — 3.00
Sulphur %	...	0.70 — 0.80
Oxygen %	...	20.00 — 24.00
Chloride %	...	0.45 — 0.60

- (ii) that the said carbonated ash has the following average composition :—

Potash (K_2O)	...	37.00 %
Phosphate (P_2O_5)	...	1.00 %
Silica (SiO_2)	...	3.50 %
MgO	...	9.60 %
R_2O_3	...	1.20 %
Calcium (CaO)	...	7.60 %

- (iii) that the spent wash as discharged from distillery is acidic in nature with 4.2 — 5.0 pH., at about 60° — 70°C. and contains about 10% solids;
- (iv) that in order to treat and concentrate spent wash in ordinary steel vessels the spent wash can be neutralised by using lime water;
- (v) that the neutralised liquor when heated in a steam jacketed vessel, can be concentrated to give a product which has the following properties :—
- (vi) that the said product when dried and ground will give a potash fertiliser, containing about 10% potash.

Sl. No.	Baume of Spent wash	Brix of spent wash	Temp. °C.	Sp Gravity	Viscosity in CP at 27°C	Remarks
1	6	10.8	27	1.04	4	
2	8.5	15.3	29	1.06	6	Material can
3	18	32.4	30	1.14	9	flow easily
4	28	50.4	30	1.23	40	
5	35	63.0	31	1.31	290	
6	37	66.6	31	1.33	725	Flow rate is
7	37.5	67.5	22.5	1.331	4500	very low.

(vi) that the said product when dried and ground will give a potash fertiliser, containing about 10% potash.

The process provides a means for manufacturing potash fertiliser from an industrial effluent, containing more than 0.7% potash, comprising in combination the steps of neutralising said industrial effluent with an alkali or an alkaline substance such as lime or milk of lime and evaporating the neutralised waste in a multiple effect evaporator to form a concentrated product.

In a preferred embodiment, said industrial effluent may be treated biochemically before neutralising with an alkali.

In another embodiment, the process may include the step of drying the concentrated

product in a drier and reduce the particle size in a grinding mill.

Plant and Equipment

Plant comprises of an effluent receiving tank, storage tank for lime or milk of lime, neutralising tank, connected to the discharge pipes of each of said effluent receiving tank and lime tank; a Multiple Effect Evaporator, comprising plurality of chambers maintained under vacuum, first of said chambers being connected to a discharge duct of the neutralising tank for receiving neutralised waste and the last of such chambers being provided with a discharge duct for discharge of concentrated product, said chambers being provided with interconnecting feed pipes which connect them in tandem so that the neutralised waste passes from the first to the last chamber in

succession, and with condensate removal pipes and non-condensable gas-outlets fitted with control valves; and a (barometric) condenser associated with the last chamber for maintaining chambers under vacuum.

Embodiments of the work will now be described by way of example, with reference to the accompanying drawings, in which—

Fig. 1 shows a schematic process chart;

Fig. 2 shows a diagrammatic sketch of the plant according to an embodiment; and

Fig. 3 shows a diagrammatic sketch of the plant according to another embodiment.

As shown in Fig. 1, the process for the manufacture of potash fertiliser comprises neutralising a biologically treated spent wash stored in an effluent receiving tank with lime or milk of lime in a neutralising tank pumping the neutralised waste through a multiple effect evaporator so that it becomes concentrated or forms what has been referred hitherto as a Zerup. This concentrated product or Zerup is then stored in a storage tank (which may also be referred to as Zerup storage tank) from where it may be either removed for direct disposal or pumped to drier where it is dried. The dried product obtained is next conveyed to a grinding mill where it is ground into a dry granulated form having desired dimension before it is packed for disposal. If desired, additional phosphate and nitrogen are added to the granulated product to form

a mixed fertilizer of any required N : P : K ratio.

The plant for carrying out such process for manufacture is shown in figs. 2 and 3. Referring to Fig. 2, the plant has a tank or lagoon 2 where spent wash is biologically treated, a pump 4 for pumping the spent wash into an effluent receiving tank 6, a lime or milk of lime tank 8, the tanks 6 and 8 being provided with discharge ducts 10 and 12, respectively, leading to a neutralising tank 14 and provided with control valves 16. The neutralising tank 14 (which may be fitted with a stirrer preferably of an anchor or imepller type) has a discharge duct 18 (provided with a control valve 16) leading to a first chamber 20 of a multiple effect evaporator marked 22 and also having a second chamber 24 and a third chamber 26.

In said evaporator, an interconnecting feed pipe 28 connects the output of the first chamber 20 to the second chamber 24 and another interconnecting feed pipe 30 connects the output of the second chamber to the third chamber. Each of the aforesaid chambers also have non condensable gas outlets; the non-condensable gas outlet 32 of the first chamber 20 opens to the atmosphere whereas the gas outlets 34 and 36 lead to a barometric condenser 38, which in known manner serves to create a vacuum in the third chamber 26 which in turn creates vacuum in the preceding chamber through interconnecting pipes 40 which also serve as outlet pipes for vapour produced from boiling liquid in each chamber. Calandria of each chamber 20, 24 and 26 are also provided with a condensate removal pipe 42 which

in case of chambers 20 and 26 respectively terminate in drains 44 while in the case of chamber 24 calandria terminates in the calandria of third chamber 26. The interconnecting pipes 28 and 30 also are each fitted with control valves 16 for draining out wash water and remaining liquid for emptying the vessel during cleaning through the pipes into sinks 46.

The third chamber 26 has a discharge duct 45 wherethrough the concentrated product is discharged for direct disposal in a concentrated form or taken for further treatment. The plant is provided with pipe connection for disposing of the concentrated product in any desired manner. Thus, the discharge duct 45 terminates at a sink 46 through a control valve 16 for draining out and through by-pass pipe 58, control valves 60 and 61 to direct discharge of concentrated product to outlet 64. The discharge duct is also connected to a first storage vessel 48 via control valve 50 and through pump 52 to (a) a second storage vessel 54 through control valve 56, (b) to a drum drier 70 through pipe 68 and control valve 72.

The drum drier dries the concentrated product. For grinding such dried product, the plant also has a grinding mill 80 which is connected with the drum drier 70 via a conveyor 82. Reference numeral 84 denotes containers for the collection of the granulated product, and reference numerals 86 and 88 denote pipes for conveying injection water to the barometric condenser 38 (by a pump 90 through flow regulating valve 92) and the tail pipe of the condenser respectively.

During operation, spent wash biochemically treated in tank 2 in the effluent receiving tank 6 is fully neutralised with lime or milk of lime in the neutralising tank 14. The neutralised waste is then passed through the pipes 18, 28 and 30 so that it is fully concentrated before being discharged through pipe 45. All the condensate is removed via condensate removal pipes 42. Vacuum in each of said chambers 20, 24 and 26 is maintained by the condenser 38 operating in known manner.

The concentrated product reaching the discharge duct 45 may either be collected in concentrated form at outlet 64, drain 44 or in sink 46 or pumped to the drum drier via pipe 53, valve 72 and pipe 68 and collected in granular form in container 84.

This plant shown in Fig. 3 is identical to that shown in Fig. 2 with like references indicating identical parts, except that the effluent receiving tank is adapted to receive effluents also from a methane gas plant 9 (where it is neutralised biochemically) and or directly from a distillery 11 without biochemical neutralisation. Another difference is that the second storage tank is eliminated such that the discharge duct 45 is connected to said first storage tank via control valve 50 and also to the sink 46 via valve 16. The storage tank 48 is only connected to a discharge pipe 94 via a control valve 96 and through a pump 52 and valve 72 in pipe 64 to the drum drier 70. The concentrated product can therefore, be collected either in a concentrated form in a tank 98 and sink 46, or in a granular form in the container 84.

Economic Study**Basis**

- (1) Plant working at Walchandnagar
- (2) Estimation : Commercial Plant of 300 tons spent wash/day
- (3) Product : Concentrated 'Zyrup' of 70° to 80° Brix.
- (4) Working days : 300 per year

Capital Investment

Estimated cost of a plant handling 300 tons of spent wash per day is Rs. 20,00,000/-.

Expenditure per annum :**Fixed**

- | | | | |
|---|-----|-----|--------------|
| 1. Interest and depreciation at the rate of 25% (15% + 10%)
(Interest on capital, depreciation on building & Plant
machinery, equipment etc.) | ... | ... | Rs. 4,00,000 |
| 2. Salaries and wages | ... | ... | Rs. 42,000 |
| (Rs. 35000/- P. M. — /4 Operatives, 1 Supervisor, 2 Fitter,
2 Unskilled Labour) | | | |

As the plant is attached to Distillery, Distillery staff are also available.

Variable

1. Steam consumption per day is 70 T. for 300 days.

	Steam rate
Fuel — Bagasse	Rs. 15/T. Rs. 2,62,500
(Available for 250 days)	
Coal (utilised for 50 days)	Rs. 40/T. Rs. 1,40,000

2. Lime requirement per day @ 4 Kg/Tonnes/day of spent wash Rs. 200/Ton.	—	Rs. 72,000
3. Power — 48 Kw. rate Rs. 0.26/KWH ($40 \times 300 \times 24 \times 0.26$)	—	Rs. 74,880
4. Maintenance 2%	—	Rs. 40,000
Total expenditure/Annum (Fixed + Variable)	—	<u>Rs. 10,31,380</u>

Concentrated spent wash—40 tons/day12,000 Tons
(containing 7.5% Potash) (Containing 900 ton Potash)

Production cost/ton of concentrated spent wash —Rs. 86.

Revenue per Annum

Market price of the potash is Rs. 1400/Tonne (Govt. rate—
Rs. 2100/Tonne)

Potash content in product per day—3 Tonnes.

Revenue/annum by selling the potash $3 \times 1400 \times 300$ —Rs. 12,60,000

Returns

Total revenue by sale — Rs. 12,60,000=00

Total expenditure —Rs. 10,31,380=00

Net profit —Rs. 2,28,620=00

The product in solid form, using drum drier, has been discontinued to avoid further steam consumption and the cost of packing material. Concentrated spent wash is now being disposed of by mixing with filter pressmud as potash rich fertilizer.

DISCUSSION AND CONCLUSION

The running plant has been designed and installed for handling 30 tonnes of pollutants/industrial waste that is, distillery spent wash per day. The useful material recovered from pollutant (distillery effluent) is 3 tonnes/day in the form of Potash Fertiliser, having following composition :

Potash (K_2O)	...	7.0%
Phosphate (P_2O_5)	...	0.15%
Nitrogen (N)	...	1.50%

Recovered material is utilised for manufacture of mixed fertiliser having desired ratio of N:P:K.

We have been using Triple Effect Evaporator. If the Quadruple Effect Evaporator is used, steam consumption will be further reduced.

We have tried biochemically treated spent wash in lagoons. In that case, requirement of lime addition is very nominal and the cost of lime consumption will be reduced by Rs. 50,000/-per year.

This method of disposal completely eliminates environmental pollution.

The product is a potash fertilizer and hence an import substitution.

This does not require extra land and water.

By the anaerobic digestion, CH_4 (methane)

gas can be recovered. This will improve the steam balance to a great extent and will boost economy.

There are indications that present world resources of potassium salts, essential in N/P/K fertilizer formulations, are tending to reach a finite limit in availability, with future possibilities of shortfalls in supply. To a certain extent, the potash and phosphate markets are geared to each other. Potash market is stable, and prices have been steady.

Acknowledgement

The author records his sincere thanks to the Management of Walchandnagar Industries Ltd. for their keen interest in the project and encouragement. The author is also thankful to the staff of Research & Development Centre at Walchandnagar, for their enthusiastic work particularly Messrs B. M. Dutt, A. P. Lad, S. R. Kalaswad and K. B. Shedji.

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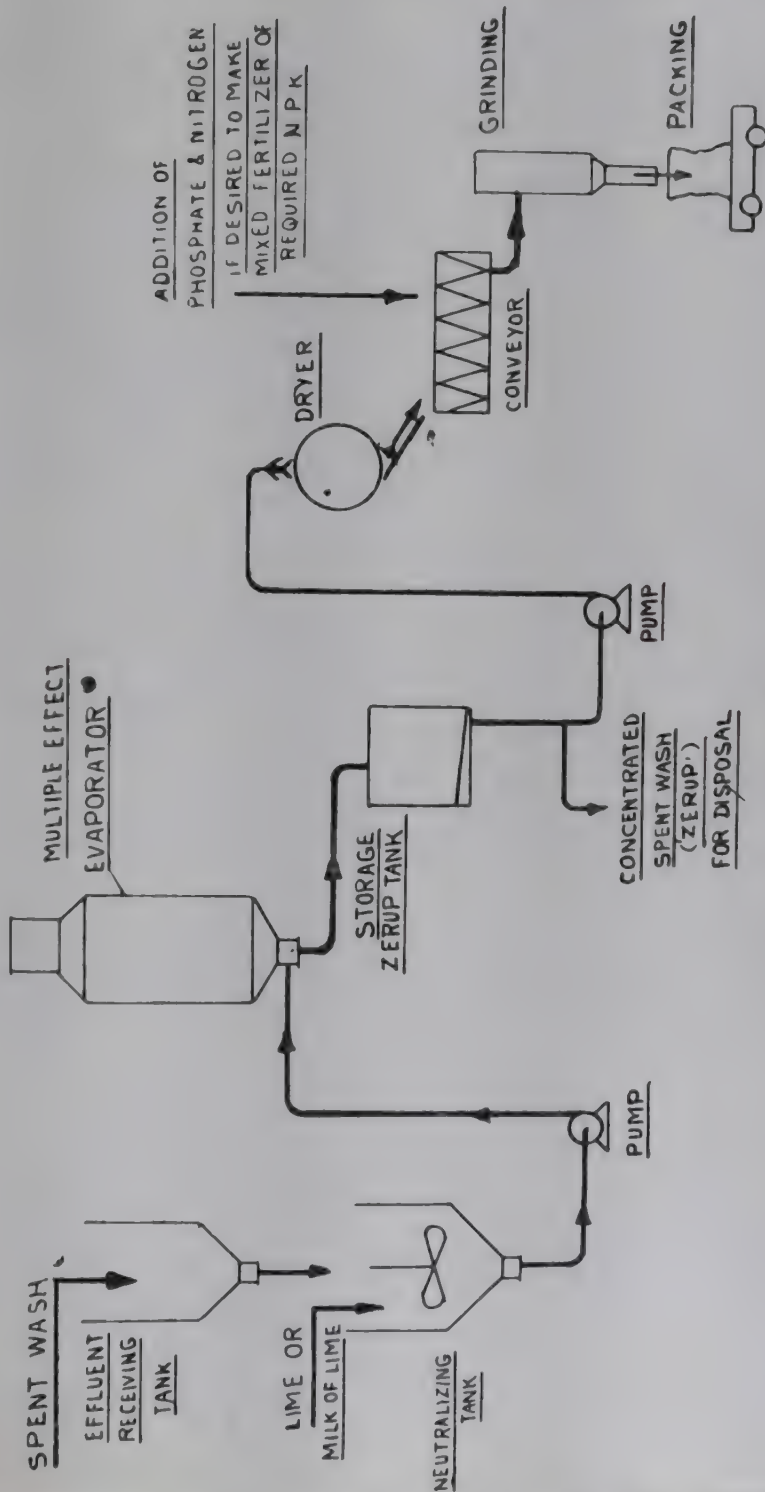


FIG NO.1

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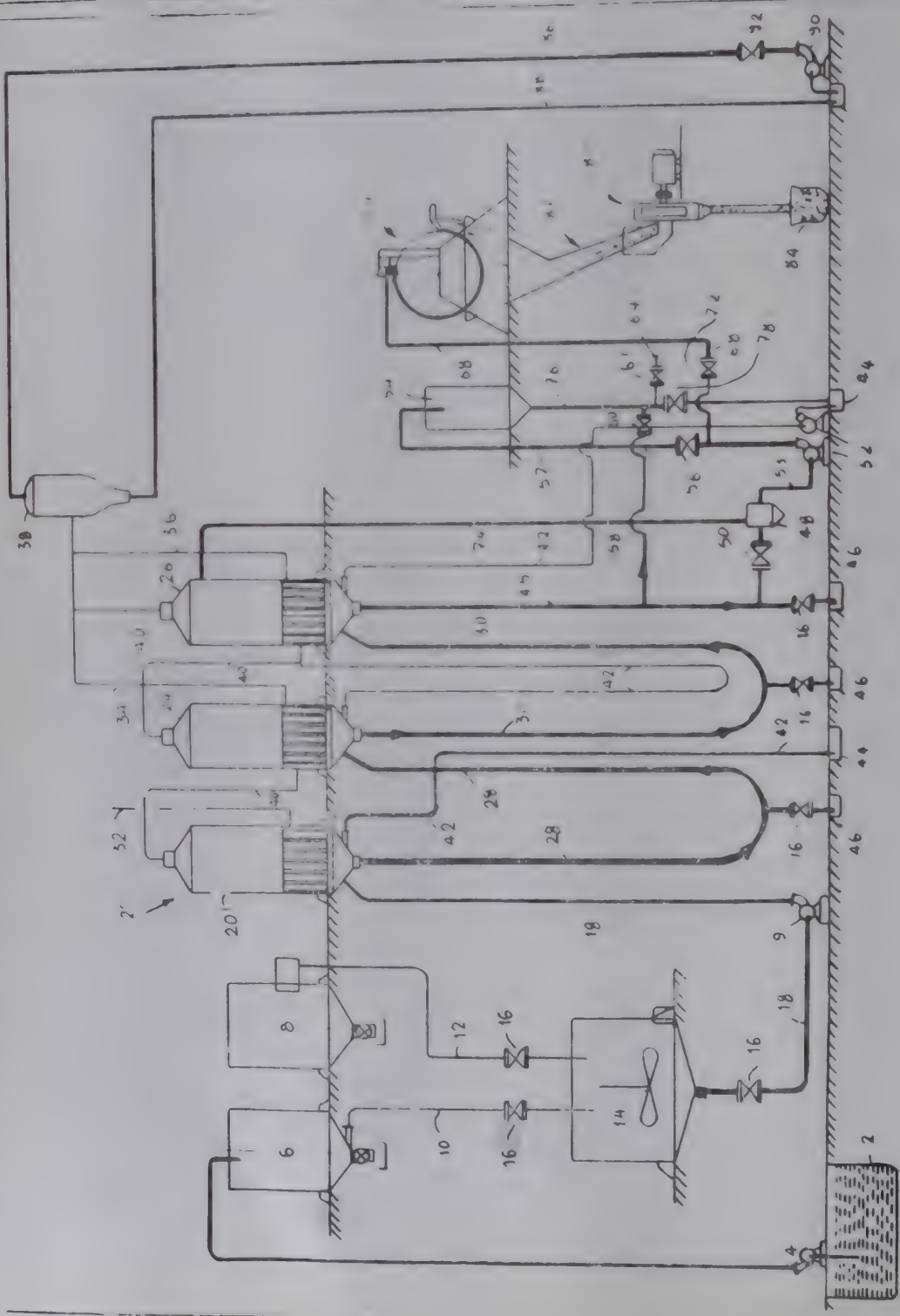


FIG NO 2

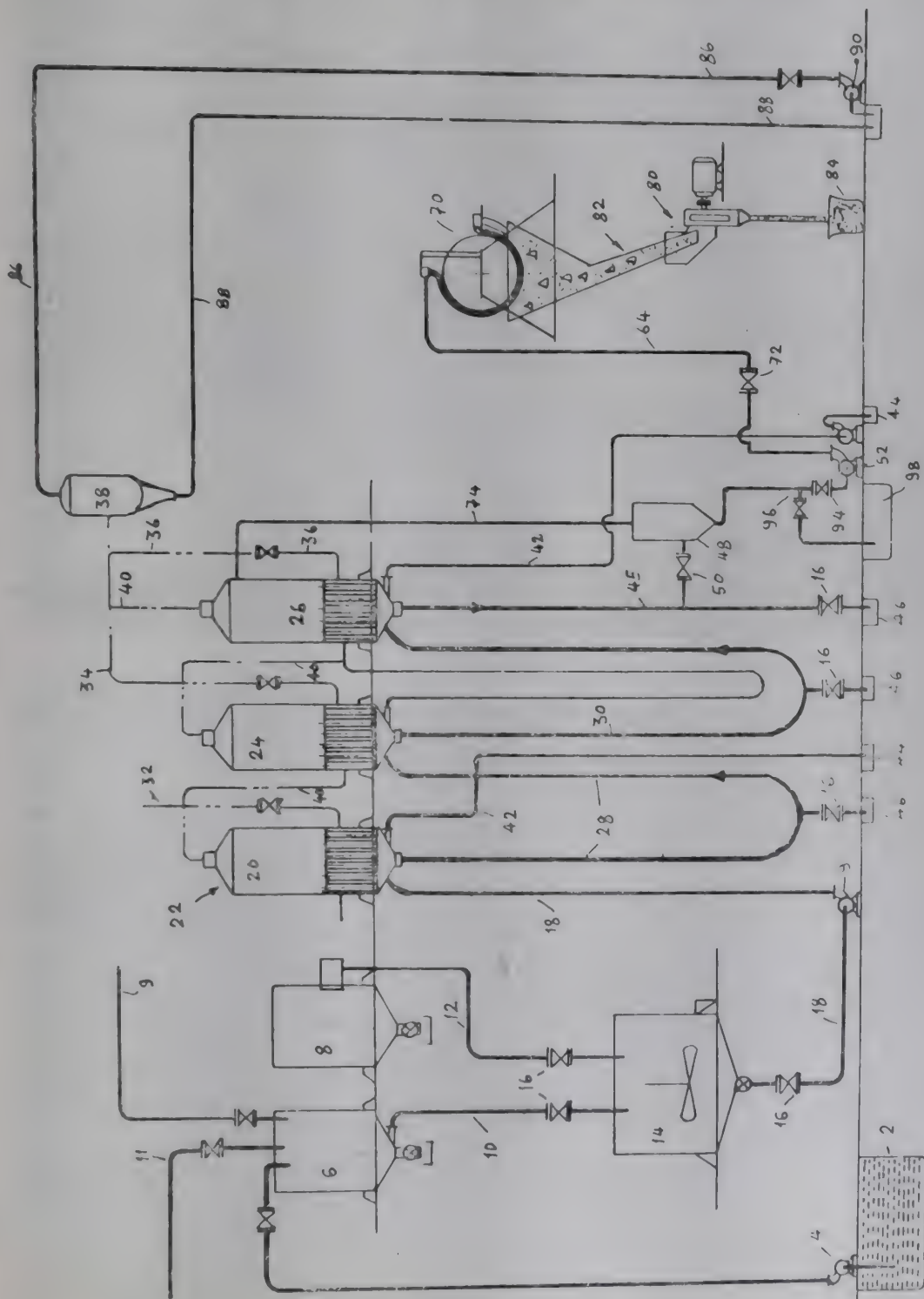
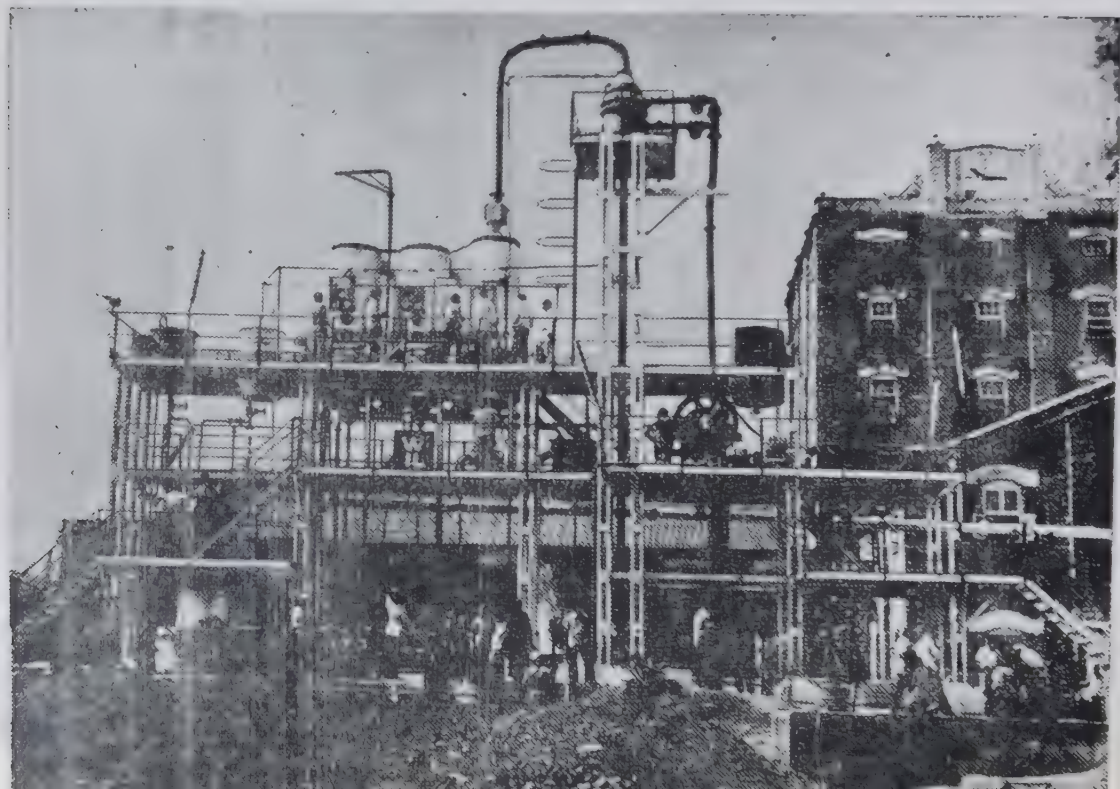
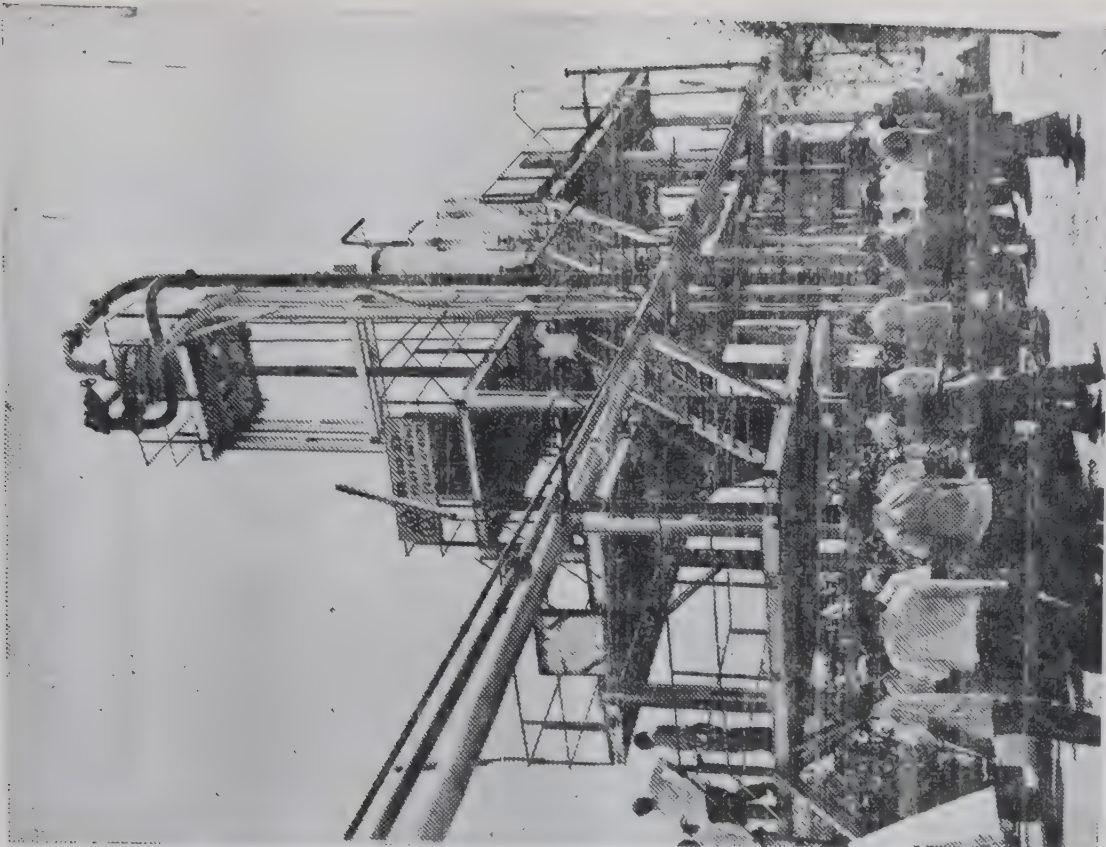


FIG NO 3





STUDIES ON THE UTILIZATION OF METHANE BY A *COCCUS* BACTERIUM FOR THE PRODUCTION OF SINGLE CELL PROTEIN

By

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ABSTRACT

A gram negative Coccus bacterium capable of growing on methane as sole carbon and energy source was isolated from biomanure and bioliquid from a biogas plant. The organism was able to grow on biogas (65% CH_4 and 35 CO_2) and air mixture under shaking conditions. The organism could not grow on methanol at concentration of 2% (V/V) and the presence of small amounts of methanol inhibited growth on methane. Other gases like Indane gas and petrol gas were not metabolised. The optimum methane to air ratio for growth of the organism was 1 : 1.5. Protein content of microbial cell mass was about 70% on dry weight basis and contained all essential amino acids to serve as single cell protein.

Introduction

The production of microal protein from hydrocarbons has been attracting the attention of people for many years, as a suitable protein source to meet nutritional problems. Cultivation of bacteria and yeasts on some fractions of petroleum has been tried on pilot plant scale. (1) The disadvantage with higher hydrocarbons or gas oil is that these are insoluble in water and thus require vigorous stirring to keep oil droplets well dispersed throughout the

medium. These substrates may have impurities which require subsequent removal from final product. During the past few years; the fermentation of single carbon compounds such as methane and methanol have drawn considerable attention due to their ample availability in pure state and at low cost. (2) Although protein production from methane has not yet been fully developed, but gaseous hydrocarbons have proved to be of great potential for use in the production of single cell protein (SCP), as gaseous hydroca-

bons are relatively pure when recovered from nature and require little processing to give high purity.

Recently, number of bacteria oxidizing methane and methanol have been reported (3) to grow well in mineral salts media supplemented with methane and air mixture or methanol as carbon source.

In previous studies in this laboratory on the production of single cell protein from methane and methanol employing an isolated *Candida* strain (4), *Coccus* bacteria used to always contaminate the culture. The present article deals with the isolation of the *Coccus* bacterial species, capable of growing solely on methane as carbon source and describes some of the characteristics of this organism. Microbial protein formed from fermentation of methane has been analysed for its amino acids composition.

Materials and Methods

Biogas

Methane gas was obtained from biogas (mixture of methane and carbondioxide in about 65 : 35 ratio) produced by anaerobic digestion of bagasse and cane trash, the cellulosic wastes of sugar industry at the biogas plant of the Institute.

Gas Purification

Methane gas was collected over water in 5 l aspirator bottles after bubbling the biogas through strong solutions of KOH, neutral lead acetate and copper turning and was

mixed with air (bubbled through same route) in required proportion.

Filling the gaseous mixture

Flasks or desiccators were evacuated with rotary vacuum pump and then filled with desired methane and air mixture. This process was repeated to ensure complete replacements of air of containers with the methane and air mixture.

Isolation of microorganism

A bacterial species growing on methane as sole carbon and energy source was isolated from bioliquid and biomanure of the biogas plant of the Institute, by enrichment and planting technique. The mineral salts medium used for isolation work contained— $(\text{NH}_4)_2\text{SO}_4$, 2 gm; KCl, 1.15 gm; $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, 0.65 gm; $\text{MnSO}_4 \cdot \text{H}_2\text{O}$, 0.045 gm; $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, 0.068 gm; $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, 0.17 gm and yeast extract (Diffo) 0.025 gm made upto one liter with distilled water and pH adjusted to 7.0. Agar plates and slants were made by adding 2% agar-agar to above salts medium. Agar petri plates or slants were placed in a desiccator, filled with methane and air mixture (50 : 50) and incubated at $36^\circ - 37^\circ\text{C}$ for 6 to 7 days. A single purified strain appearing on plates and giving high biomass production was taken in liquid salts media and exposed to methane + air mixture in 500 ml Erlenmayer flask (fitted with side arm tube) and kept on rotary shaker for 72 hours and tested for biomass production at regular intervals. This strain was used in all further studies.

Active culture was maintained and grown under shaking condition in 1 l Erlenmayer flask fitted with airtight stop cocks, containing 150 ml liquid medium. After inoculation of flasks with air uniform suspension of microorganisms, the air inside the flasks was replaced by methane and air mixture and then incubated on a rotary shaker (about 150 rev/min.). Batch growth studies were done in 500 ml Erlenmayer flasks containing 70 ml liquid medium with appropriate inoculum. A typical growth curve is shown in Fig. 1.

Cell Concentration

Growth of the microorganism was monitored by measuring turbidity on Klett Summerson photoelectric colorimeter using filter No 42 or measuring O. D. at 420 mμ on Beckman spectrophotometer model — B. Turbidity readings were converted to dry cell wt. (using a standard curve prepared from gravimetric procedure.)

Manometric Studies of gas uptake

The pressure change, representing combined CH_4 and O_2 uptake by washed cell suspension was determined manometrically (5), using Warburg's apparatus at 30° C. Methane grown cells were washed with 0.05 M phosphate buffer, pH 7.0, resuspended in same buffer and 0.3 ml of cell suspension (containing 0.45 mg dry cell wt.) was placed in the side arm of Warburg flasks. The main compartment contained 1.7 ml mineral salts medium and the central well contained 0.2 ml 20% KOH and a filter paper wick. The flasks were attached to manometers and the air in the flasks was replaced by methane air mixture

or other desired gases by evacuation procedure (6).

Chemical Composition

Nucleic acids were extracted by the method described by Herbert *et al* (1971) (7) DNA was estimated by Burton's method (8) and RNA by orcinol method. Protein was estimated by Lowry's method after extracting nucleic acids and dissolving the residue in 0.5 N NaOH at 80°C for 5 min.

Amino Acids Composition (Chromatographic method)

0.5 gm dry cells were hydrolysed with 20 ml 6 N HCl at 120°C by refluxing on an oil bath for 18-24 hours. The hydrolysate was desalted by passing it through a column of a cation exchange resin (Amberlite IR-120) and the absorbed amino acids were eluted with 2 N ammonia solution and concentrated under reduced pressure at 60°C (9). Amino acids of the hydrolysate was identified by two dimensional paper chromatography using Butanol : Acetic Acid : water (4 : 1 : 5) and Phenol water (80 : 20) solvent systems.

Results and Discussion

The organism isolated was a gram negative, *Coccus* bacterium growing on methane as sole carbon and energy source. It was strictly aerobic in nature and could not grow on nutrient-agar slants. The organism grew well on methane and air mixture, and biogas and air mixture (1 : 1.5) in mineral salts medium (Table — 1 Fig.—1) Growth on biogas and air mixture was as good as on purified methane and air mixture. This showed that presence

of CO_2 (at about 14% concentration in the biogas air (40 : 60) mixture used) did not interfere with the growth of organism on methane. Methane and oxygen gaseous mixtures containing 10% CO_2 have also been reported to be suitable for the cultivation of bacteria on methane. Earlier studies from this laboratory on a methane utilizing *Candida* strain, however, showed that the presence of CO_2 stimulated the growth of the culture. So this suggests the possibility of utilization of biogas as such, without any purification to remove CO_2 , in the production of single cell protein.

The isolated microorganism was not able to grow on methanol at a concentration of 2% (V/V). It has been reported that methanol was extremely toxic to many strains even at a low concentration of 0.01% (W/V) whereas, some strains tolerate methanol upto 1.5% (W/V) (12). Only a few strains can grow on methanol without needing prior adaptation. Methanol is also reported to inhibit the oxidation of methane (12). Our results showed that methanol, at a concentration of 0.05% (V/V), inhibited methane oxidation (Table-1).

Various methane to air ratios have been reported to be utilized by different organism. Our manometric experiments on gas uptake showed that methane and air mixture at a ratio of 1 : 1.5 was more readily metabolized than at other ratios (Table-2). The same ratio was also used by Dworkin and Foster (1956) for cultivation of their organism *Pseudomonas methanica* on methane (13).

The microorganism isolated was tested for its ability to utilize other hydrocarbon gases such as, petrol gas and Indian gas. As shown in Table-2, these gases were not metabolized by the culture. As these gases are the mixture of gaseous hydrocarbons higher than C-1 (containing mostly propane, butane and pentane), this showed that the culture is highly specific to methane. The slight change in pressure, — 5.0 mm/hr and — 6.5 mm/hr (corrected values with endogenous oxygen uptake) for Indane gas and petrol gas respectively, may be due to the presence of carbon monoxide gas which is known to be oxidised by methane utilizers. (14).

Protein and nucleic acids contents of methane grown cells are shown in Table-3. The protein content of isolated bacteria was about 70% (dry cell wt. basis) and this value is in good agreement with reported value for other organisms. Hydrolysate of the microbial protein contained all the essential amino acids (Fig. 2 & 3). The higher protein content together with presence of all essential amino acids in the product recommends it for use as single cell protein.

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Table-1
Growth of the Culture on different Substrates

Substrate	Increase in O. D. after 48 hours incubation	Cell mass formed (mg/ 100 ml)
(1) Biogas + air (1 : 1.5)	0.65	17.50
(2) Methane + air (1 : 1.5)	0.67	18.00
(3) Methanol (2% (V/V))	0	0
(4) Methane + air (1 : 1.5) with added Methanol (0.05 %, V/V) in the medium.	0.53	14.00

Table—2**Rate of Uptake of Different Gases by Methane Utilizing Culture.**

Particulars	Maximum rate of change in pressure (— mm/hr.)*
1) Methane : air (1 : 0.5)	30.0
(2) Methane : air (1 : 1)	30.0
(3) Methane : air (1 : 1.5)	36.5
(4) Methane : air (1 : 2)	31.5
(5) Methane : air (1 : 4)	28.0
(6) Indane gas : air (1 : 2)	13.5
(7) Petrol gas : air (1 : 2)	15.0
(8) Endogenous	8.5

* minus (—) sign show decrease in pressure due to uptake of gases.

Table-3

Comparison of Protein and Nucleic Acid Contents of Methane Utilizing Bacteria.

Organism	Crude protein content as % of dry cell wt.	Nucleic Acids %			Reference
		RNA.	DNA.	Total	
(1) <i>Methanomonas-margaritae</i>	62				Takeda <i>et al</i> ¹⁵
(2) <i>Methylomonas Sp. A7 3670</i>	65				Marrinago <i>et al</i> ¹⁶
(3) <i>Mixed culture (TM 10)</i>	71				Bewersdorff <i>et al</i> ¹⁷
(4) Isolated coccus bacteria	70	5.75	3.91	9.66	Present work

Table—4**Amino Acid Separated by Two Dimentional Chromatography**

Spot No.	Amino Acids.
1.	Cystine
2.	Ornithine
3.	Lysine
4.	Arginine
5.	Histidine
6.	Aspartic Acid
7.	Glutamic Acid
8.	Serine
9.	Glycine
10.	Threonine
11.	Alanine
12.	Tyrosine
13.	Tryptophan
14.	Methionine
15.	Valine
16.	Proline
17.	Phenylalanine
18.	Leucine and Isoleucine

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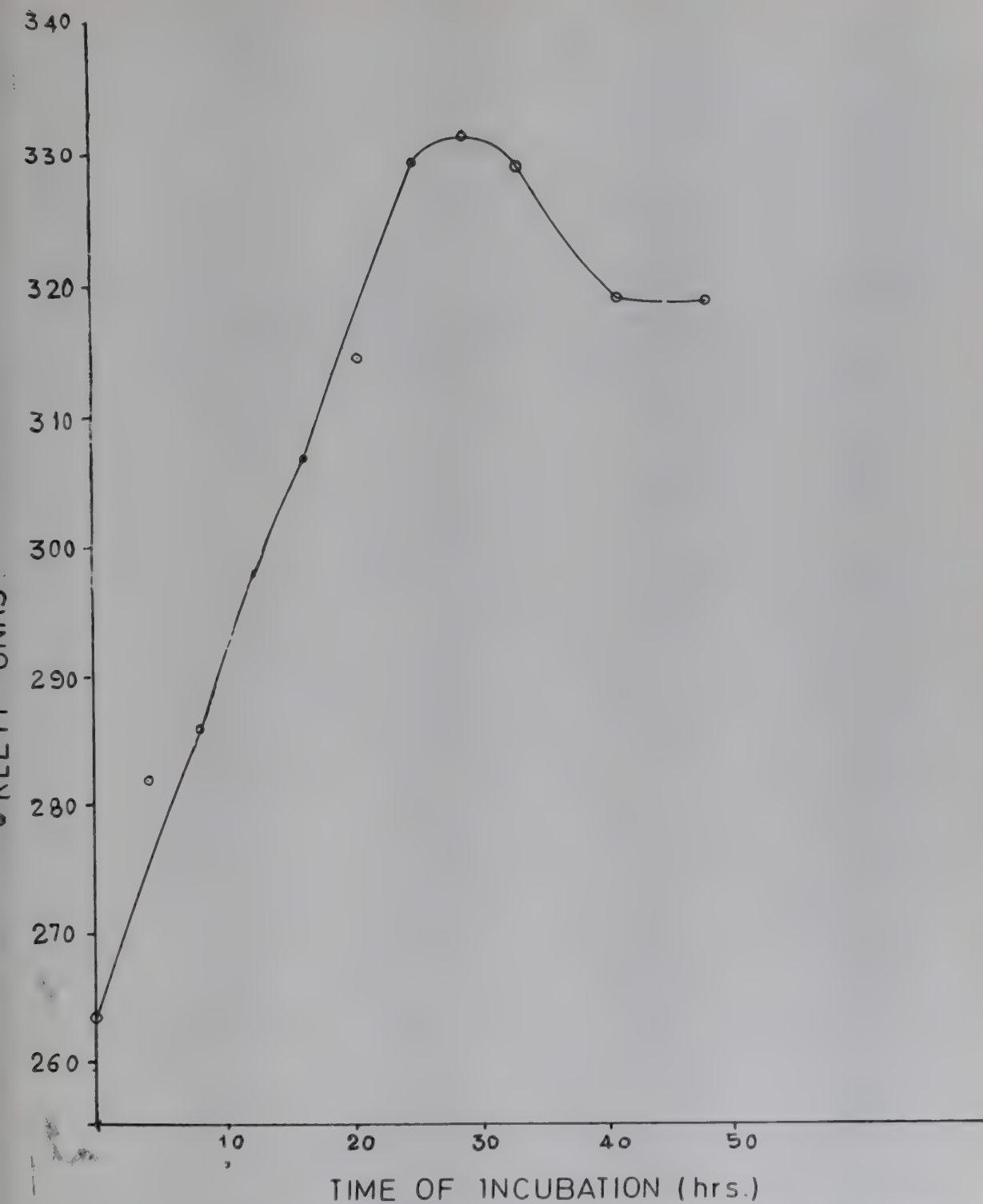


FIG. 1 GROWTH CURVE OF METHANE GROWN CULTURE

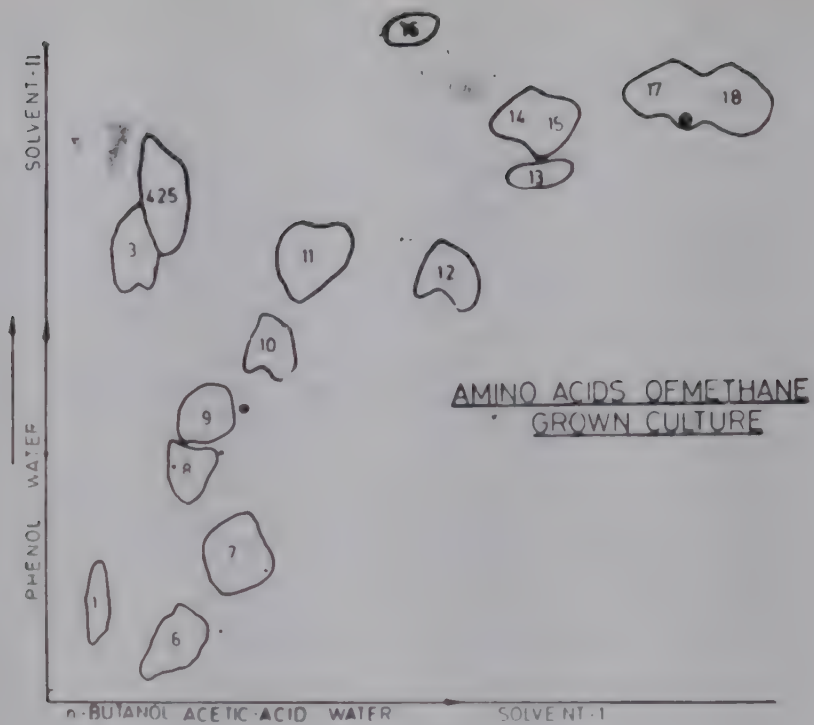


Fig. 2

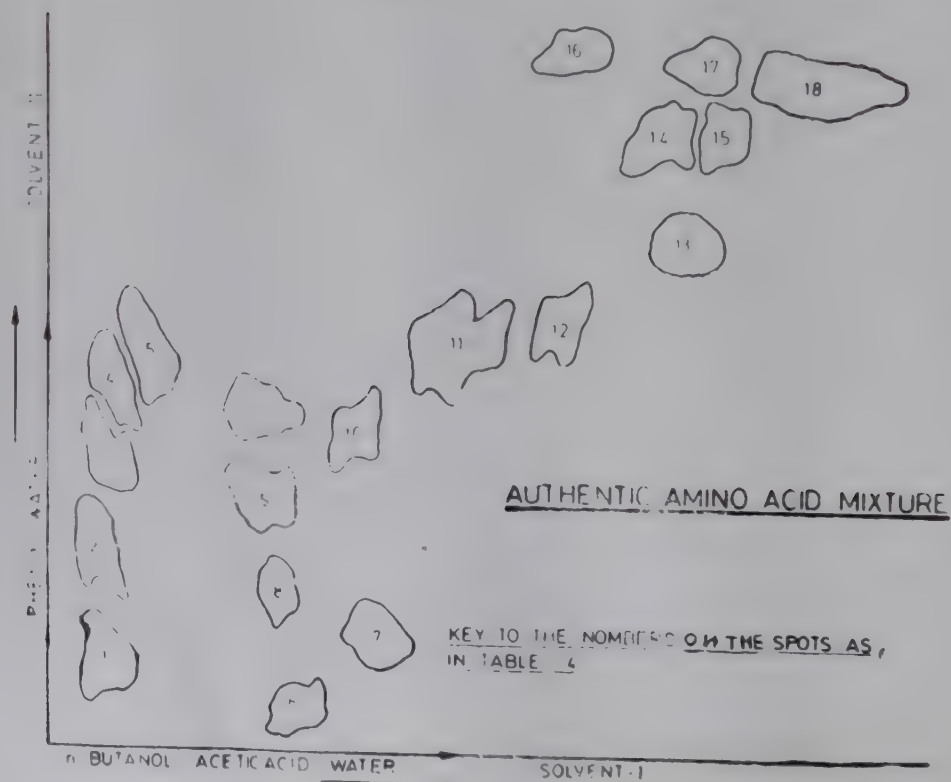


Fig. 3

DISTINCTION BETWEEN VACUUM PAN AND KHANDSARI SUGARS BY DIRECT AND ALTERNATING CURRENT POLAROGRAPHIC STUDIES BASED ON VARIATION IN ANIONIC SURFACE ACTIVE SUBSTANCES

By

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ABSTRACT

The clarified juices of the vacuum pan sugar factories with more inherent non sugars are boiled as such for production of direct consumption white sugars, while those of open pan khandsari sugars are produced with juices having lower non sugars but higher surface active compounds, concentration, as derived from the addition of vegetable or chemical antifoaming agents employed during boiling, marking a difference in the quality of the final products. Khandsari sugars, therefore, gave well defined irreversible D. C. polarograms having half wave potential at 1.45 ± 0.05 V vs S. C. E. while A. C. peaks were exhibited at -1.70 ± 0.04 V vs. S. C. E. In poor quality khandari sugars, the adherence of S. A. S. on the mercury droplets was so strong, that desorption was not possible and the droplets did not coalesce even after hours. Good quality vacuum pan sugars could well be contrasted for absence of any a. c. or d. c. polarograms, while poor quality sugars indicated tensametric peaks only. This difference in behavior was utilised for distinguishing the two types of sugars.

Introduction

India is producing about 140-150 million tonnes of sugarcane, 30% of which is employed for the manufacture of vacuum pan direct consumption white sugar, 7 to 10% for the open pan khandsari sugar, 50% for the jaggery and rest for the chewing and seed purpose.

The quality of the khandsari sugars has undergone spectacular improvement in the last two decades, as a result of which many technological improvements are taking place and the whiteness and brilliance of this sugar is often such that it becomes difficult to differentiate between vacuum and open pan sugars,

Authors^{1,2} made exhaustive studies on the nature of the trace impurities in vacuum pan and khandsari sugars as a result of analysis of a large number of samples. The differential behaviour was sought in the high value of supersaturation employed for the crystal growth in the khandsari sugars, which resulted in the cocrystallisation, deposition and inclusion between the crystal lattices of many of the organic and inorganic impurities derived from the mother liquor or as a result of the process conditions. These were because of the employment of bells having series of open pans for concentration of the juice right upto the brix of the massecuite (or rab) and necessary use of antifoaming substances like caster seed slurry to suppress the vigorous foam generated during boiling. The caster seeds, rich in glycerides of many saturated and unsaturated acids result in addition of series of surface active compounds. The higher turbidity and low filterability of the khandsari sugars were attributed to this important difference in the technique of manufacture. The broad characteristics of such sugars were listed in Table 1. Distinguishing feature in the quality of two types of sugars lied in their chemical specification like CaO-content and conductivity. Latter studies³ made on the poor quality vacuum pan sugars yielded values of even 70 to 80 mhos cm^{-1} and so the maximum limit for vacuum pan sugars was revised to 100 mhos cm^{-1} and the minimum value for the khandsari sugars was set at 100 mhos cm^{-1} , though usual values for these were always found on much higher side.

The presence of a trace amount of surface active substances cause marked variation in the properties of sugars. This aspect has been

well recognised by International Commission for Uniform methods of Sugar Analysis (ICUMSA) as subject-19 characteristics of the white sugars" which deals primarily with the quality variation based on such impurities and has drawn wide appreciation of the impact of surfactants as controlling the quality of the sugars. This is evident from the proceedings of their last two Sessions held in London in 1970 and in Ankara in 1974. A wide range of methods of determination of the surfactants in sugars were presented and are as under :

- [a] The Coca Cola test⁴ tentatively adopted at the 15th session of ICUMSA.
- [b] Spreekels test⁵ also based on floc formation.
- [c] Foam Test⁶ to measure generation of foam due to the presence of surface active compounds.
- [d] Alcoholic floc Test⁷.
- [e] Polarographic test as developed by Zimmermann⁸ based on suppression of Oxygen maxima.
- [f] Polarographic test as developed by Moroz⁹ based on the formation of different maxima on the polarograms.
- [g] Polarographic test as suggested by Ramaiah¹⁰ and Trevedi based on the oxygen wave having half wave potential of -0.76 V, correlating the diffusion current with concentration of the surfactant.

The present work aimed at the study of the polarographic behavior of the sugars after eliminating all the cationic impurities inclu-

ding those that are surface active in nature and studying the anionic fraction left therefrom. The method aims at studying the polarographic behavior of the sugars by cutting off all cationic impurities that often give the polarograms as a result of cathodic reduction. The method is not based on the suppression caused to the oxygen wave, which was the basis of the earlier studies, for evaluation of the surface activity of the sugars.

Experimental

A manual polarograph as assembled was suitable for A.C. and D.C. polarographic techniques. 30 and 29 grade direct consumption white sugars, both of sulphitation and carbonation processes, were taken for the polarographic analysis. Some good quality khandsari sugars which appeared superior in whiteness and brilliance to those of the vacuum pan process, were also taken along with ordinary khandsari sugars to study the suitability of the tests developed. The sugars in the desired concentration ranges, were passed through a cation exchange resin IR-120 column to eliminate traces of cationic impurities, which incidentally also removed all suspended or insoluble matter as well. The supporting electrolyte consisted of equal volumes of 1N KCl and a buffer consisting potassium biphthalate-HCl of pH 2.6. In some cases buffers of even pH 2.1 were also taken.

A series of commercial surface active substances which are often employed in sugar and khandsari industries for suppression of foam, viscosity and surface tension and which are known as consisting primarily of surface active compounds were analysed for their D.C.

and A.C. polarographic behavior in pure solution.

Results and Discussions

Figs 1 and 2 give typical sets of results obtained on subjecting white sugars of vacuum pan process during D. C. polarographic analysis. It may be seen from fig. 1 pertaining to two concentration of a particular sugar of 29 grade (poor quality) that the curve showed an increasing trend of the current beyond the potential of $-1.7V$ and did not acquire any saturation value as is normally indicated by the limiting current values in a polarograms. Change of the concentration on either side did not give any saturation value either. Similar was the condition with 30 grade sugars and typical curves presented in fig. 2 showed an identical behavior. Similar nature was shown by all vacuum pan sugars of sulphitation or carbonation quality that were examined. This indicated the absence of any reducible oil or substance under the experimental conditions. It has been shown by many workers that sugars themselves would not interfere in these determinations. This showed the absence of any reducible substance in the sugars as such under the experimental conditions, though the sugars as such gave positive Coca-Cola and Foam tests, when used as such without any pretreatment.

Typical sets of results obtained for khandsari sugars of different qualities were given in Fig. 3 to 6. These sugars after the above treatment gave well defined curves. Such cases were also found where the saturation values or the limiting current values were obtained only for a short span. Thus well defined curves were

obtained for a khandsari sugar at 3, 4 and 5% concentration (see Fig. 3). The half wave potential values at these concentration was -1.45 V vs. S. C. E. The third grade khandsari sugars gave even more well defined curves at 0.8, 1.2 and 1.6% (See fig. 4). Higher concentrations of even 4 to 8% were employed in cases of better quality khandsari sugars (see Fig. 5). Similar nature was indicated by other khansari sugars also, the curves for which were not returned. The apparent difference in quality could easily be seen from the concentration of the sugars required to be employed in order to obtain measurable current values.

The extent of the presence of anionic S. A. S. was found to vary from sugar as may be seen from Fig. 7, where in relationship between concentration of the khandsari sugars and current in different sets of observation were given. It was interesting to observe a linear relationship as per Ilkovic's standard equation and confirmed reduction of a particular specie (s) giving similar diffusion curves. The inclination of the curves differed as a result of different amounts of the reducible species in the same amount of sugar. In general higher inclinations were given by the poorer quality. The irreversible nature of the reduction of the surfactants present in the sugars was established, from the the plots of

$$\log \frac{i}{i_d - i} \text{ Vs. } E \text{ d. e. where 's' is the current}$$

corresponding to the potential 'E' d. e. and 'id' to the diffusion current. The slope of the curves, which is equal to $-0.052/n$ gave the value of 'n', the number of electrons involved for the five samples as 0.32, 0.32,

0.31, 0.36 and 0.28 which were all less than 1. The values of 'n' were also determined from the potentials at $\frac{3}{4}$ and $\frac{1}{4}$ of the diffusion current generally termed as $E_{\frac{3}{4}}$ and $E_{\frac{1}{4}}$ (see Table 2], wherein values of less than 1 was obtained in all cases, establishing to the irreversible nature of the reduction of the surfactants present in khandsari sugars.

It was thus possible to assign a particular morn for the determination of anionic S. A. S. in the khandsari sugars. It may be pointed out that the Coca Cola and foam tests showed presence of much higher concentration of total S. A. S., the results were, however, not given for lack of reproducibility during the determinations.

A. C. Polarographic Studies

Most of S. A. S. of catlonic, anionic and and nonionic nature exhibited well defined A. C. peaks. It was established only recently [communicated] that most of the S. A. S. exhibited tensametric waves having summit potential ≈ 1.6 V vs S. C. E., even in those cases where irreversibly reduoible polarograms were exhibited on D. C. polarography. A large number of vacuum and open pan sugars were examined by A. C. polapographic technique as well. It is interesting to point out that non of the vacuum pan white consumption sugars gave any A.C. peak when examined after elution through cation exchange resin. In contrast, the khandsari sugars gave particularly sharp peaks even in very good quality samples as may be seen from typical sets of curves presented in Fig. 8 to 11. The peak potential was found at -1.70 ± 0.03 V, and was quite sharp. An additinal peak was also

found in certain cases at -1.1 to -1.2 V. The main peak acquired improved values of current at such high concentration as 35 to 40% where the peak value of -1.70 V observed at lower concentrations, could not be recorded because of the immense increase in current. Poor quality khandsari sugars showed A.C. peaks only at low concentrations. The formation of a large number of small droplets of mercury collecting at the base of the polarographic cell, which did not coalesce even for considerably long intervals, was generally seen with all khandsari sugars.

Fig. 12 gives typical sets of results obtained on subjecting the commercial surface active composition to D.C. polarographic analysis¹³. It was indicated that the curves were essentially similar in nature indicating diffusion current values generally having half wave potential ($E_{\frac{1}{2}}$) at -1.5 V vs. S. C. E., even at small concentration of the surface active composition. It was difficult to obtain the saturation potential corresponding to the limiting current. Similar behaviour was indicated during the analysis of these composition by A.C. polarographic technique. In most of the cases, the diffusion current values increase beyond a potential of -1.3 V vs. S.C.E. The saturation value was not obtained in either case which was akin to the observation made by the author with pure surface active substances like cetyl pyridinium, sodium lauryl sulphate, dodecyl etc. In such cases formation of small droplets of mercury was observed when the applied potential was beyond -1.5 V. These droplets accumulated in polarographic cell and their coalesce took considerable long time and some time hours. The dropping mercury electrode behaved in all these cases

in an erratic manner yielding current values of very high order which could not be recorded. It was felt that the traces of S.A.S. If retained on the commercial sugars would result an extremely high current values during A.C. polarography,

It may be pointed out that D.C. waves gave half wave potentials from -1.45 to -1.50 V., while A.C. peaks had summit potential at -1.70 ± 0.03 V vs S. C. E. This confirmed¹² that D.C. polarograms corresponded to the irreversible reduction of the anionic surfactants present in the khandsari sugars, while A.C. peaks were due to the accumulation of the surfactants and were tensametric in nature. It may, therefore, be coincidence only that the half wave potentials and peak potentials could be observed in close potential region and their formation is based on entirely different physico-chemical properties.

Khandsari Sugars gave well defined irreversible D.C. polarograms having half wave potential at $\approx 1.45 \pm 0.05$ V vs S.C.E., while A.C. peaks were exhibited at -1.70 ± 0.05 V vs S.C.E. In poor quality khandsari sugars, having a higher concentration of the surfactants, well defined D.C. polarograms could be observed at low concentration of the sugars.

It was thus established that the presence of anionic surfactants in khandsari sugars could be evaluated by both the polarographic techniques. The results were not in direct correlation with the floc forming potentiality or the foaming characteristics of the sugar. The method offered potentiality of quantitative analysis of anionic S.A.S., not only in sugars but in other pure and technical solutions.

Acknowledgement

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Table—1

Different Behaviours of Vacuum Pan and Khandsari Sugars.

S. No.	Characteristics Analysis	Vacuum Pan White Sugars	Open Pan Khandsari Sugars
1.	Pol	99.8—99.95 (99.9)	99.4—99.9 (99.7)
2.	Reducing Sugar	0.004—0.25 (0.05)	0.10—0.40 (0.15)
3.	Moisture	0.04—0.15 (.05)	0.15—0.50 (0.2)
4.	CaO mg/100 g.	10—35 (15)	45—80 (60)
5.	SO ₂ p.p.m.	5—25 (10)	5—25 (10)
6.	Colour O.D. 400—O.D. 550	0.02—0.06 (0.04)	0.04—0.15 (0.08)
7.	Viscosity c. p. (40% Soln)	20—30 (25)	20.30 (25)
8.	Conductivity $\times 10^6$ mhos	3—15 (10)	50—200 (100)
9.	Turbidity %	10—30 (15)	40—70 (50)
10.	Filterability Fk	0.3—2.5 (1.0)	50—400 (100)
11.	Shape of Crystals	Monoclinic	Flattened monoch- mic or cuboid

The Values within brackets give the average.

Table—2

Determination of the values of number of Electrons involved in the polarographic reduction.

Nature of the sugar	Sample No.	Concentration of solution in %	$E_{\frac{1}{2}}$	$E_{\frac{1}{4}}$	$E_{\frac{3}{4}}$	n
Khandsari Sugar	1	5.0	-1.46	-1.53	-1.58	0.976
		4.0	-1.445	-1.52	-1.37	0.976
		3.0	-1.45	-1.525	-1.36	0.941
	2	1.6	-1.44	-1.52	-1.363	0.961
		1.2	-1.46	-1.53	-1.33	0.976
		0.8	-1.47	-1.515	-1.36	0.961
	3	3.0	-1.53	-1.60	-1.445	0.961
		2.5	-1.53	-1.60	-1.45	0.952
		2.0	-1.535	-1.60	-1.45	0.976
	4	8.0	-1.57	-1.63	-1.49	0.403
		6.0	-1.57	-1.63	-1.49	0.403
		4.0	-1.58	-1.62	-1.455	0.941
	5	8.0	-1.56	-1.62	-1.47	0.976
		6.0	-1.55	-1.62	-1.44	0.913
		4.0	-1.54	-1.61	-1.41	0.982

I	35%
II	25%



FIG 1 D.C. POLAROGRAMS OF VACUUM PAN WHITE SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

I	35%
II	25%

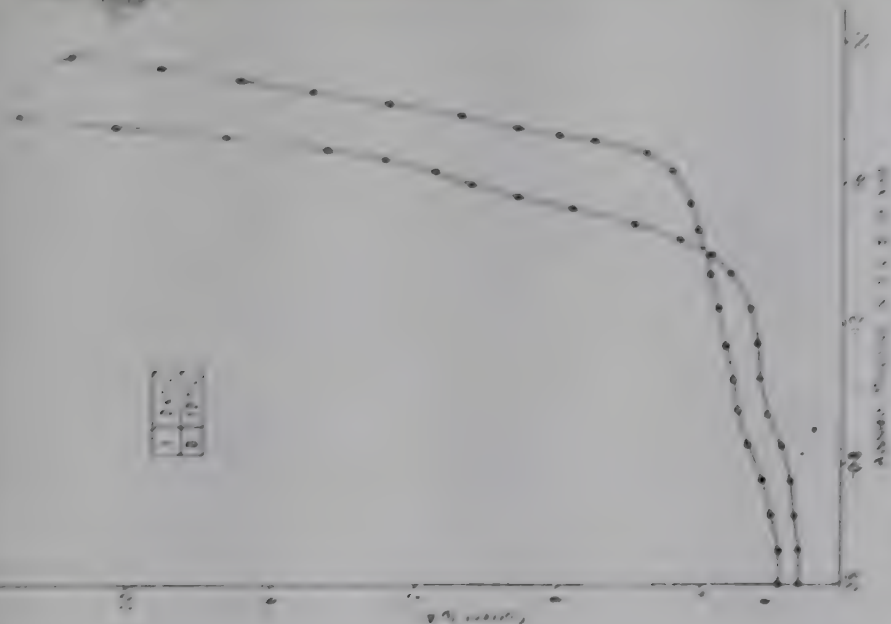


FIG 2 D.C. POLAROGRAMS OF TWO VACUUM PAN WHITE SUGARS AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN



Fig. 3 D.C. POLAROGRAMS OF THE SURFACTANTS PRESENT IN KHANDASARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN



Fig. 4 D.C. POLAROGRAMS OF THE SURFACTANTS PRESENT IN KHANDASARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

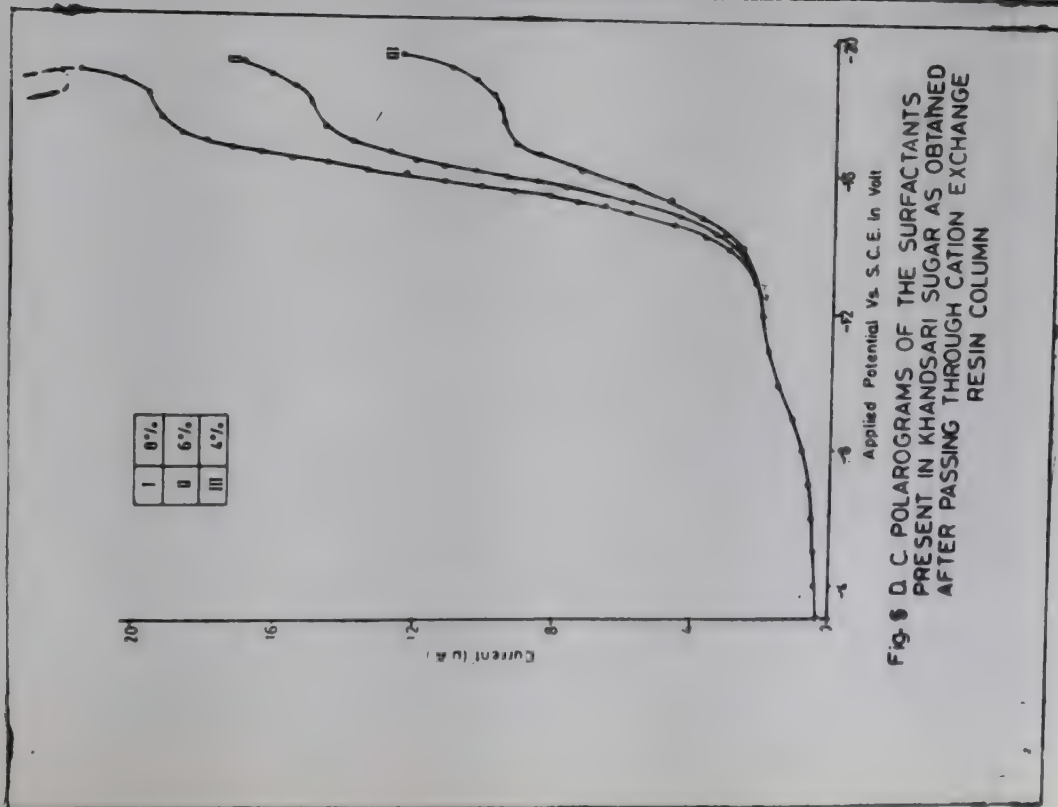


Fig. 5 D. C. POLAROGRAMS OF THE SURFACTANTS PRESENT IN KHANDASARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

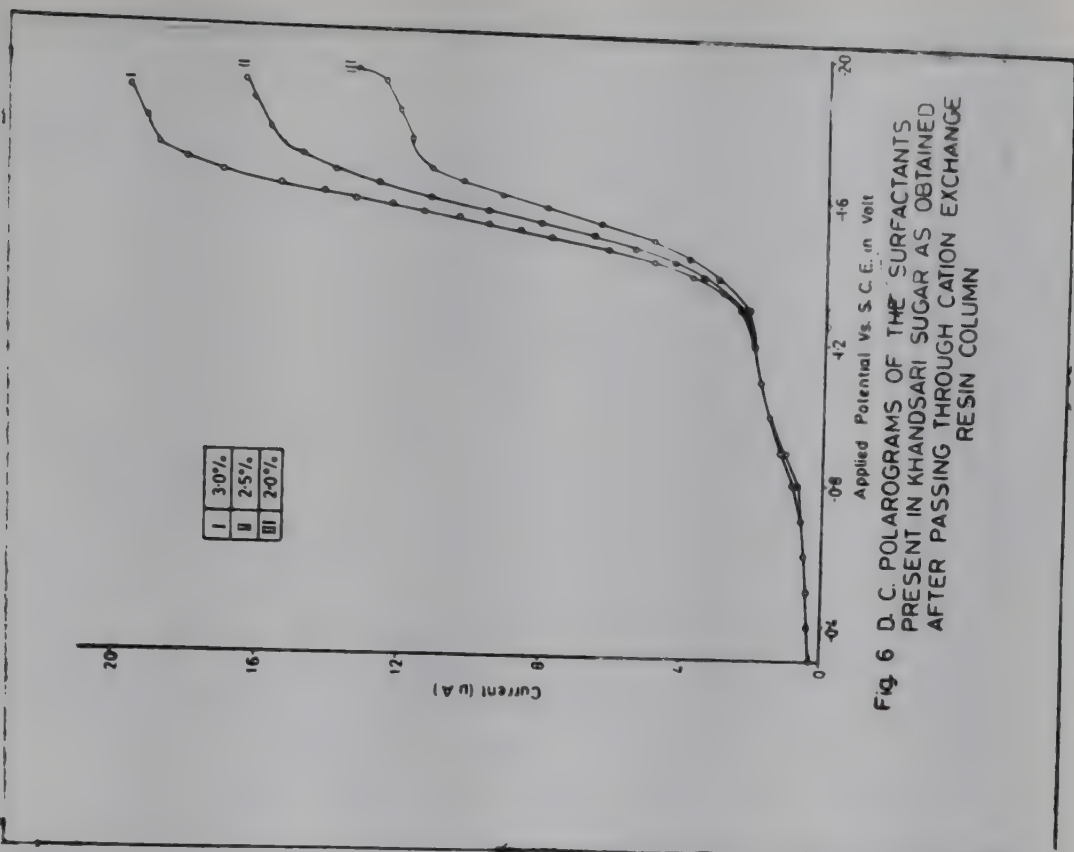


Fig. 6 D. C. POLAROGRAMS OF THE SURFACTANTS PRESENT IN KHANDASARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

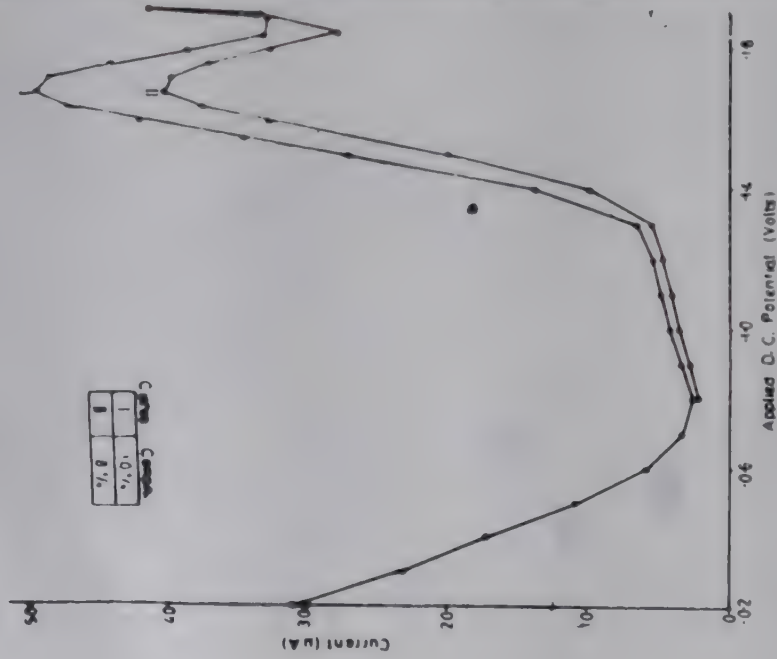


Fig 8 A.C. POLAROGRAMS OF THE SURFACTANTS PRESENT IN KHANDSARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

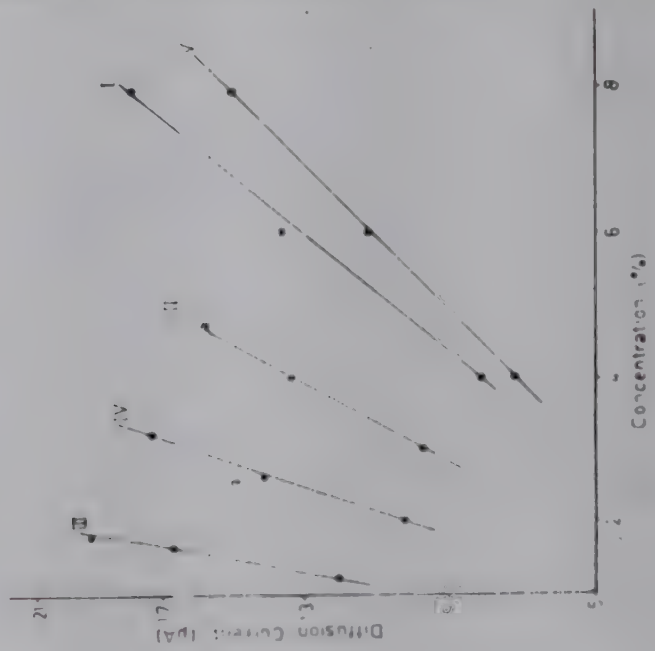


Fig 7 SHOWING THE LINEAR RELATIONSHIP BETWEEN DIFFUSION CURRENT & CONCENTRATION IN KHANDSARI SUGAR

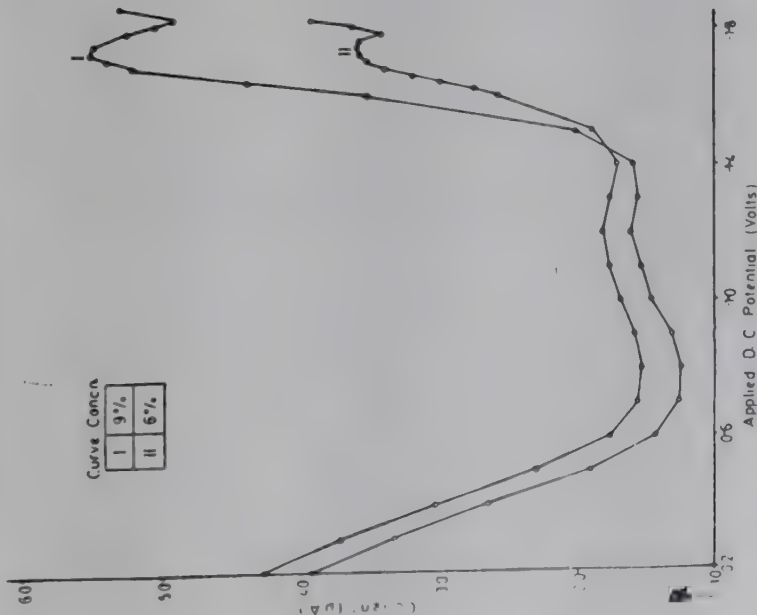


Fig. 9 A.C. POLAROGRAMS OF THE SURFACTANTS PRESENT IN KHANDSARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

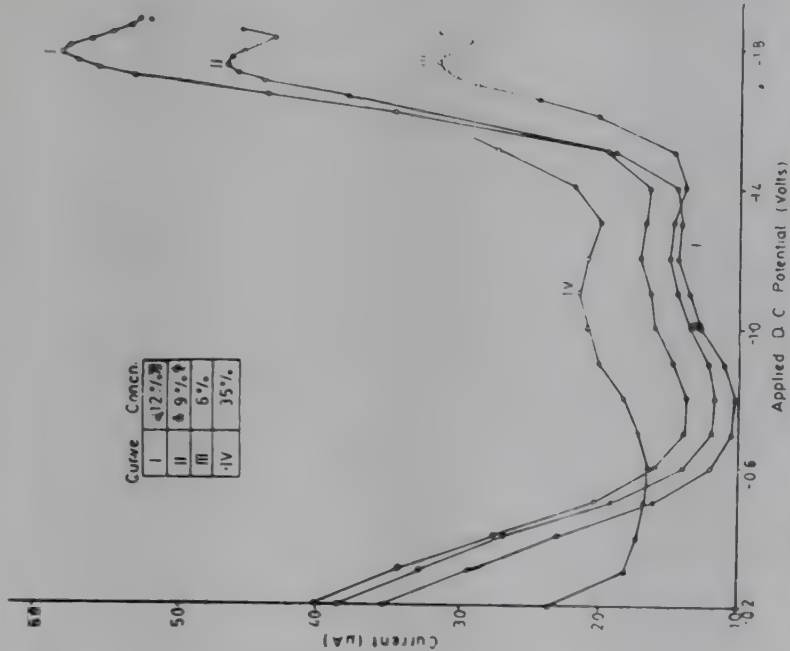


Fig. 10 A.C. POLAROGRAMS OF THE SURFACTANT PRESENT IN KHANDSARI SUGAR AS OBTAINED AFTER PASSING THROUGH CATION EXCHANGE RESIN COLUMN

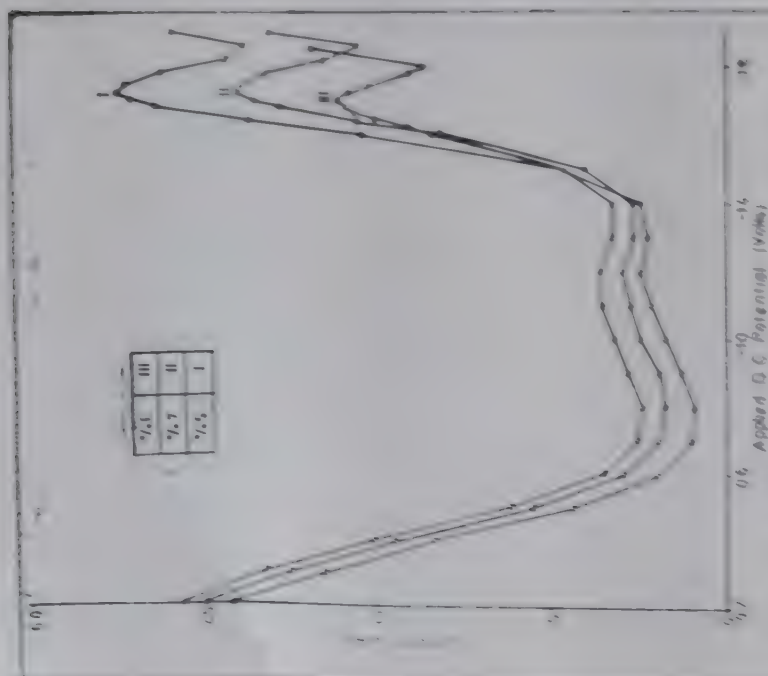


Fig 11 A C Polarograms of the Suppactants Present in Khandsari Sugar as Obtained After Passing Through Cation Exchange Resin Column

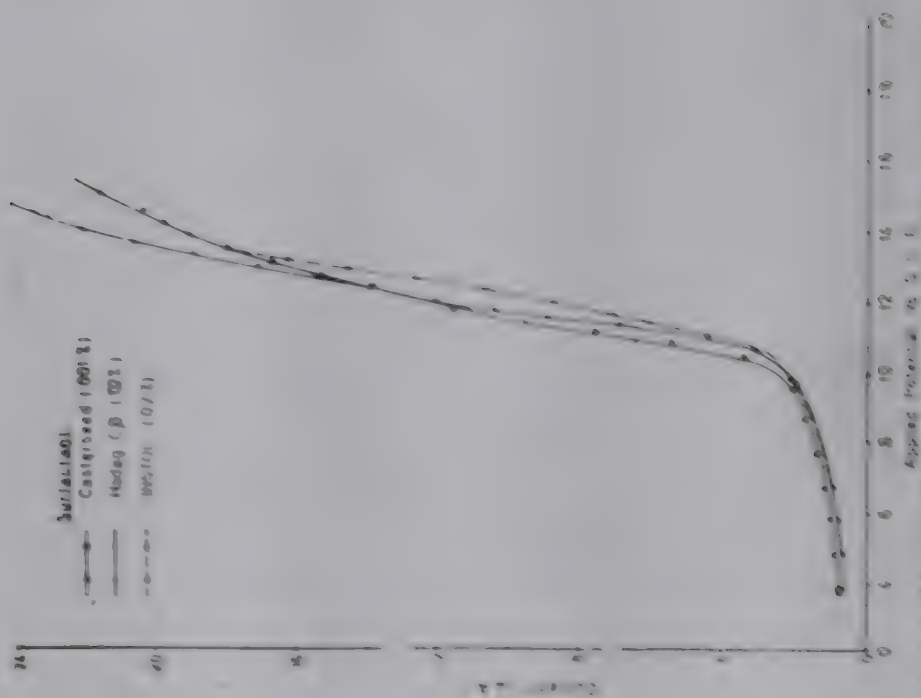


Fig 12 D.C. Polarograms of Some Commercial Supplantants in Use in Sugar Industries

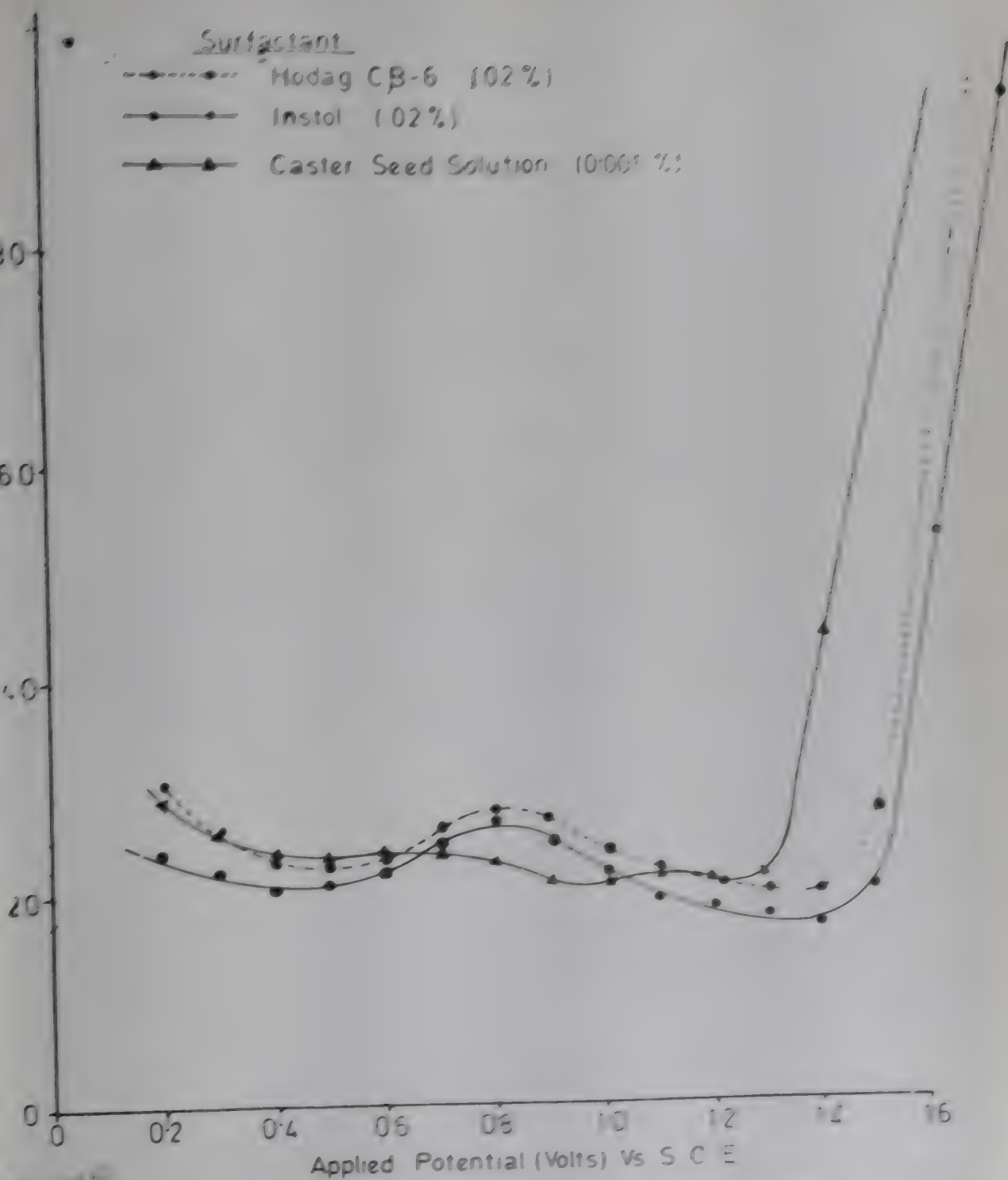


Fig. 13 A.C. POLAROGRAMS OF SOME COMMERCIAL PREPARATION IN USE IN SUGAR INDUSTRIES

UGANDA AND ITS SUGAR INDUSTRY

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ABSTRACT

Uganda "The pearl of Africa" is situated at the very heart of Africa. The land and weather of Uganda is one of the best in the world. It was exporting sugar to all the neighbouring countries of Africa. After the declaration of economic war the condition had changed and it is importing sugar. However the Government of Uganda have taken positive steps to rehabilitate the sugar Industries and it is hoped that with in a couple of years it will again be one of the major exporting countries of Africa.

Introduction

Uganda, which was described by the late Sir Winston Churchill as the "Pearl of Africa" is situated in the very heart of Africa. It was ruled by the British for a period of 100 years and got independence on 9th October, 1962. It is one of three East African countries and the smallest. Uganda is bounded on the North by the Sudan; on the West by the Zaire Republic; by Tanzania and Rwanda to the South; and spreading out widely Eastwards is the Republic of Kenya. The distance from North to South of the country is about 643.72 Kilometres and from East to West about 563.25

Kilometres with a total area of 235.880 Sq. Kilometres of which approximately 42,486 Kilometres are open water. This area of open water consists of parts of Lakes Victoria, Mobutu and Edward and all of Lakes Idi Amin and Kyoga. From Lake Victoria at Jinja, the River Nile begins its 6080 Kilometres journey to the Mediterranean. At Jinja, from the Owen Falls, the most of the power is generated by Hydro Electric system. Uganda is self sufficient in power and supplies power to its neighbouring countries and hence there is much scope for many industries to be put up in future. Lake Victoria is 1130 metres above sea level, in the North at the Sudan frontier

the altitude is only 610 meters. The ground rises towards Mount Elgon (4315 metres) in the East and towards the Rwenzori Mountains in the West. The highest peak of the snow capped Rwenzori range is 5188 metres, the third highest mountain in Africa.

Over most of the country, the weather is that of perpetual summer, with hot sunshine, cool breezes and showers of rain. Temperature ranges, Entebbe (International Airport) about 17.5°C (62-64 F) minimum and 26-27°C (77-81 F) maximum. The mean annual rainfall at Entebbe is 63.44 inches. The rain is wide spread throughout Uganda from April to November and fairly dry from December to February with occasional thunder storms rain. The weather is neither hot nor cold throughout the year with a pleasant breeze in the evening and hot sunshine in the morning. There was no major floods, no cyclones, or typhoons in the history of Uganda for the last 100 years and there is no crop damaged for want of rain had been heard of for the last 20 years.

Population of Uganda, according to the 1969 census is over 9.556, millions, and analysis of the African population showed that there are numerous tribal groups represented in Uganda, the largest being the Baganda just over one million followed by the Iteso, Banyankole and Basoga with about half a million each. Twenty four other tribes showed totals in excess of 10,000 each. Due to various tribes, present in Uganda, the languages are also various in different districts though the main language is English, Swahili and Luganda.

Uganda has three National Parks, the most

popular is the Marchison Falls National Park which covers an area of 3900 sq. Kilometres. The Queen Elizabeth National Park covers an area of 2500 sq. Kilometres. Kidepo Valley National Park is much smaller covering an area of 1400 sq. Kilometres on the borders of Sudan in the North Eastern Uganda. (Presently the names of the first two National Park have been changed as Kabalega Falls National Park and Rwenzori National Park).

Beyond the National Parks which are Uganda's top attractions, the land is usually extraordinarily fertile and verdant with well farmed valleys and as in areas such as Kigezi, in the South West, the terrain consists of terraced hill sides, cultivated from top to bottom, interspersed with beautiful wild flowers.

Having a land locked country, Uganda is dependent principally upon the port of Mombasa at Kenya. Arrangement also have been made to import and export its commodities through port of Khartum at Sudan and Djibouti of Seichelis. There are 1237 Kilometres of Railway line mainly of metre gauge, in Uganda between Tororo and Kasesa and Tororo and Pakwach. Due to breakdown of East African Community, lack of wagons, engines coaches spare parts and technical personnel the Uganda Railways are facing a lot of problems to transport its goods. However, arrangements are being made to restore the normality and in the near future it will be in a position to handle most of its goods through Railways.

There are more than 35,000 Kilometres of roads of all sorts, of which 2226 Kilometres

are bituminised main highways and another 250 Kilometres are being bituminised.

The electricity generation is mainly by hydro-electric power from the Owen Falls of River Nile at Jinja and there are a few diesel generators also (say at Arua). In the year 1976 an amount of 66 million K. Wts was generated. Uganda is not only self-sufficient in electricity but supplies power to its neighbouring countries and there is much scope for increasing the hydro-electric power.

Uganda's main industries and crops are coffee, cotton, tourism, copper, some rare metals and tea. Its coffee is accepted as one of the best coffee in the world and fetch a very high price in the international market.

The main imports are: transport, machineries, spare - parts piece goods and base metals

Both imports and exports have increased considerably since 1972. Since 1971 due to heavy imports of Air Cargos-transport and other commodities, the balance of international payments was always unfavourable to Uganda until 1975. During 1977 there was the first time, a net foreign exchange stock of 5500 million U. S. Dollars with the Bank of Uganda. This boom of balance was mostly due to increase of coffee prices in the international market and export of other commodities including sugar. This favourable balance has been maintained this year too.

The prosperity of Uganda has attracted world attention, especially among the so-called developing and developed countries. The experience of Uganda in the economical tra-

nsformation from colonial to independent within so short period is of unique value for reference to many countries with similar ambition. This valuable experience gives rise to the rapid expansion of international cooperation of Uganda with the East and far-East countries. Due to good relation with the Arab countries, Uganda's economic development has been rapid.

Since the Economic was started in Uganda during the year 1972, several closed industries had been opened and production increased. When President Amin declared this Economic War all the Asians mostly Indians had to leave the country leaving behind all the sugar factories belonging to them. During that time there were three sugar factories in Uganda, all owned by Indians. Since then one more sugar factory had started production and another one is under construction. Negotiations for a few more factories are still going on.

When the Indians left, they left not only with the machineries but also with vast developed cane fields but took away with them the know-how of sugar production and the technical management of sugar industries. Previous to Economic War, Uganda was one of the major exporters of sugar in EEC and to the neighbouring East African countries. But due to lack of technical know-how and other reasons beyond the control of the Uganda Government the production of sugar declined rapidly and the position became so critical that there was no other alternative except to import sugar from some other countries (Including India). In this juncture the

Government of Uganda has taken is positive step to train some of its young boys in India, in the National Sugar Institute, Kanpur and an other sugar factory, to get them experienced and get practical knowledge of sugar production. They invited Indian Technologists and Engineers to run their factories and renovate the sugar industry in Uganda. Some Italian contractors also lend their helping hand to renovate one of the sugar factories.

The natural environment of Uganda is so favourable to sugarcane that it does not require any irrigation or major fertilisers. Except a little phosphate deficiency in some of the soils, the major part of the land of Uganda is very fertile. The intermittent rain, with moderate showers, helps the entire crop good germination and up-keep. There are no major pests or diseases so far located with the cane varieties grown in Uganda especially Co-627, Co-421.

The only difficulty is the weed control. If proper weed killing chemicals or labour is introduced properly, one can easily get an average of 125 tons of sugar cane per hectare without much expenditure and difficulty.

Except for three months. i.e. December, January and February, there are no dry months in Uganda and during these months, there are occasional rains too. If these three months are avoided for planting there are no reasons why the cane will not grow its full maturity and sugar of its highest purity. The quantity of sugar in cane is also comparable to the Maharashtra cane of India, specially Co-419. It is always more than 87 to 88 purity with a high Brix. If harvest time and crushing time is minimised, then the recovery will be more than 11-11.5% on cane.

Uganda's manufacturing sector, including sugar, is relatively small. Over the nine year period 1956-1974, the contribution of the sector to monetary gross domestic product (GDP) ranged between 9% and 12%. A number of manufactured products including sugar, had over the years, developed beyond the import substitution stage, and had found export market within East African Community and in the neighbouring African states. The table below shows the production of sugar between 1966-1974. It can be seen from the table that the production of sugar declined very rapidly due to various reasons.

Table-I

Production units		Average growth p.a. %							
Sugar Acreage	1966	1967	1968	1969	1970	1971	1972	1973	1973
1000 hectares	20.8	23.1	27.1	31.8	31.6	29.1	17.3	19.0	26.0-6
Production 1000									
Tons	131.1	139.6	154.9	140.0	144.2	141.3	121.4	68.6	41.0 24.9

Sugar production is hardly 25% of the production than that of 1968 at present.

In 1975 the production further declined to only 23 thousands tonnes due to various reasons and instead of exports there was no

other alternative but to import sugar from the friendly countries including India.

The table given below shows the exports of sugar from Uganda from 1966-1975.

Table 2

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	% p.a.
Sugar quantity in 1000 tonnes value	4.9	33.0	37.1	47.9	23.3	0.4	1.3	—	—	—	—
In million Shs.	4.7	28.5	30.0	35.7	19.0	0.4	0.2	—	—	—	—

1. Sh. = 0.99 Rupees

It can be seen from the table that once sugar was giving much foreign exchange to Government fund but the present state of sugar industry in Uganda is not only a burben to the Uganda Government but also much more due to huge import of sugar and running the sugar factories under heavy losses.

There were three sugar factories in Uganda prior to Economic War and departing the Indians. After that, in 1973 one small factory was closed due to mechanical trouble and in 196 one new factory was commissioned and started production. Let us analyse one by one what was the major defect in Uganda's sugar industry about its such a low production.

Kakira Sugar Works :

Kakira Sugar works started operation on a small scale as early as 1918 with jaggery as the output by an Indian. The basis of the present sugar factory was laid in 1930. It is a large establishment comprising of a factory, a nucleus sugar cane estate and a cane out grown scheme. The sugar works is presently owned by the Government. The nucleus estate covers 21,500 acres of which 19,500 acres are under cane. Production per acre is about 40 tonnes of cane. The sugar factory has an installed capacity of 90,000 tonnes of sugar a year. But current production is around 18,000 tonnes per annum or 20% of the installed capacity. The basic reasons for the under capacity operation of the factory is the dilapidated state of machinery in the factory,

workshop and plantation. Another reason for the present low capacity operation of the factory is the lack of technical know-how, lack of skilled management and maintenance staff, and the incidence of poor industrial relations. The result of all these deficiencies is the frequent breakdown of machinery which leads to frequent work stoppages and shortage of sugar in the country.

The present Government had taken a positive step to renovate the factory at a cost of Shs. 285.0 million of which Shs. 260.0 million will be in foreign exchange. Already an Italian firm has signed an agreement with the Uganda Government to undertake the rehabilitation work and renovating the factory is in progress. It is expected that the factory will be started with its expanded capacity during 1979 and the present production will be elevated further and technical personnel will be recruited from outside to train the local people.

Uganda Sugar Work Lugazi

This Sugar Factory started production in the year 1934 by another Indian and presently owned by Government of Uganda. It is a complex establishment comprising of a factory capable of production 60,000 tonnes per annum, a nucleus cane estate covering an area of 27,000 acres; and cane out growers scheme within a radius of 15 miles from the factory. Production of sugar at Lugazi has dropped sharply in recent years. Current production is estimated at around 10,000 tonnes per annum or only 16% of the installed capacity. The machines in the factory are very old. The factory also faced with serious

management and maintenance problems. Lack of technical skill much elevated the machinery breakdown and the machineries deteriorated much faster than it should be. The Uganda Government proposes to rehabilitate the Lugazi Sugar Factory in three phases. The first phase of renovation programme is estimated to be Shs. 110.00 million of which Shs 50.00 million will be in foreign exchange.

Already an Indian firm has taken the contract for the rehabilitation study of the factory and the work in this regard is in progress. After submitting the report the Government will take appropriate action in this regard.

National Sugarcane Work (Kinyala) Limited

Kinyala Sugar Factory is the country's newest sugar works, having started operation in 1976. It was first financed by an Indian firm in 1969 but after departing the Asian the present Government took it over and completed the erection in the year 1976. Kinyala Sugar Works is an integrated scheme made up of a nucleus plantation with a cane acreage of 6500 hectares and a factory with an installed capacity to produce 45,000 tonnes of sugar per annum.

At present the factory is producing only 50 tonnes of sugar per day or 30 per cent of the installed capacity. This is due to a number of problems facing the sugar works. The problems experienced includes shortage of plantation labour forces resulting from lack of accommodation and shortage of adequate food supply for the workers; lack of transport for the sugarcane. A sustained labour recruitment campaign, coupled with improved

employment conditions, have been launched by Government in a bid to raise and maintain stable labour supply for the sugar works.

Sango Bay Estate

This factory had been closed down in the year 1973 due to its boiler trouble and no arrangement had been made to renovate this factory.

One more sugar factory is coming up in the Nile Province and being financed by a private company of Uganda. Negotiations with an Indian firm are completed and plantation of sugarcane had already been started. It is expected that sugar will be coming out from the factory during early 1980.

Besides all these. President Amin, during the last Independence day message, had declared a tax exemption for any new investment over Shs. 7 million in new sugar factory to be built up by any company whether it is by Ugandan or by outsiders. Besides tax exemption, Government will provide land and help building the factory in all respects and no tax will be deducted till 50% of the invested money is accumulated or sent to its

present investor-in convertible currency. Due to this reason many multinational company showed interest to build sugar factories in Uganda.

Average cost per ton of cane is Shs. 45 in Uganda and cost of sugar as per Government price is Shs 7.00 per Kg. where as outside open market price is Shs. 35.00 to Shs. 40.00 per Kg. If a well planned organisation comes out to build a sugar factory in Uganda, it is expected that the money thus invested can be recovered within 4-5 years after it starts producing.

In a nutshell, the land of Uganda is much favourable for cane cultivation also very little as compared to any developing nation. Labour also not much costlier but transport and harvesting is a little difficult and preferably mechanical harvesting-loading and unloading is to be done for the new and to the existing factories for efficient running of the plant. Concession is there. skill labour is also not so rare if proper guidance is given to them. If these are fulfilled, then the future of sugar industry in Uganda does not seem to be so bad as it was in the last 3-4 years.

UTILIZATION OF BAGASSE FOR THE PRODUCTION OF MICROBIAL PROTEIN

By

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ABSTRACT

The effects of physical and chemical treatment of bagasse for its utilization as a substrate for microbial protein production has been investigated. Treatment of bagasse with 5% NaOH and 1% H₂SO₄ for 5 and 80 minutes or 2 hours helped in improving the utilization of the material by Rumen and Bioliquid bacterial culture but 10% H₂SO₄ treatment for 2 hours at room temperature showed better results only for the standard Cellulomonas culture. Steaming and pressure cooking in combination with sodium hydroxide improved the rate of utilization of the substrate. Treatment with ammonia and separation of bagasse into fibre and pith portions before treatment did not show any significant effect on microbial growth.

Introduction

The ability of microbes to produce food for human and animal nutrition has been recognised for over fifty years. It has been demonstrated that protein of good nutritional quality can be obtained from microorganism such as yeast, bacteria or fungi when they are grown on various organic materials (1-4).

Approximately one-third of the organic materials produced in nature is cellulose. This cheap and abundant complex polysaccha-

ride is assimilated by microorganisms having high cellulolytic activity. Presence of lignin in the plant material depresses the activity of microorganisms⁵. Due to complex nature of carbon source in cellulose, the protein synthesizing mechanism of micro organisms is heavily burdened.

One of the largest cellulosic waste in our country is bagasse, a fibrous residue of cane stalk. Bagasse availability in the country is estimated at 67 million tonnes which is mostly being used as fuel in the factory. It is a

lignocellulosic waste consisting of 46% cellulose, 25% hemicellulose and 20% lignin. Very little work has been done in the utilization of bagasse for the production of protein.

Eventhough, the degradation of cellulose in nature is extensive, the useful microbial degradation is difficult and slow. The growth of the microorganisms on cellulosic substrate depends largely on the nature of the substrate and the type of microorganism. Growth is abundant on denatured or pretreated cellulose. Therefore, proper pretreatment of substrate before microbial fermentation is important for the success of the the microbial (SCP) protien production from various cellulosic substrates. Although various pretreatment of cellulosic materials have been proposed (6-11), their effectiveness varies depending on the nature of the substrate. Thus, optimal pretreatment must be established for each substrate.

The present study deals with some of the methods for the pretreatment of bagasse to improve its utilization by microorganisms.

Materials and Methods :

Isolation of the Cultures.

The cellulolytic bacteria were isolated from rumen liquid and bioliquid (liquid waste of Biogas plant utilizing bagasse as raw material) by enrichment culture technique using basal salt medium with 1% treated bagasse as sole source of carbon. The cultures were further purified by plating. All the isolates showing cellulolytic activity were propagated and maintained in basal salt medium containing filter paper as a carbon source. The culture were screened for biomass production

from bagasse. One strain each from Rumen and Bioliquid which showed high biomass sythesis were maintained on slants and taken up for further studies.

Medium :

The growth medium¹² for cellulolytic organisms consisted of basal salt solution with 1% bagasse. The composition of the basal salt solution was :

NaCl-69, $(\text{NH}_4)_2\text{SO}_4$ -1.09, RH_2PO_4 -0.59
 $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$ - 0.1g, $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ -0.1g.,
 yeast extract 0.5g and one litre of distilled water. The pH of the medium was adjusted to 7.5.

Preparation of the substrate-Bagasse

Sugar cane bagasse was washed thoroughly with water and dried in sun. It was then kept in an air oven at 30°C for drying. The dried bagasse was ground in an electric grinding machine having 1.7mm size mesh sieve. This bagasse powder was then sieved through a 65 mesh (I.S.S.) seive. This 65 mesh powdered bagasse was taken for further treatment.

Pretreatment —The following pretreatment methods for bagasse were carried out —

1. Sodium Hycoroxide 5 and 10%

10 gram quantities of powderd bagasse were suspended in 100 ml of 5% or 10% sodium hydroxide solution in seprate beaker for 5 min, 10 min, and 2 hours respectively at room temperature (30-35°C). The contents were filtered off and bagasse was washed with distilled water to remove alkali, the washing were essed with pH paper and the bagasse dried in an oven and taken up for growth studies (Fig. 1,2,3 and Table-1).

The growth studies were followed by taking 100 ml of sterile basal salt medium (pH 7.5) containing 1% of treated bagasse powder in 250 ml Erlenmeyer flasks and kept in rotary shaker (150 rev/min) at 32° for 4-5 days after inoculation. A 48 hour old running culture was used as inoculum. In all, the growth studies 10% inoculum was used and the change in growth was observed by noting the turbidity at regular intervals on a klett Summerson colorimeter using 420 m μ (blue) filter. The growth of the isolated cultures were compared with a standard strain of *Cellulomonas fimi*-12108 (IAM culture Collection, Japan).

2. Sulphuric Acid 1% and 10%

10 gram quantities of powdered bagasse were suspended in 100 ml of 1% or 10% sulphuric acid respectively for 2 or 20 hrs. at room temperature (30-40)°C. Content were filtered off and bagasse was washed with distilled water. The treated, dried bagasse was taken up for growth studies (Fig. 1, 2 & 3).

3. Combined effect of acid and alkali treatment

In this treatment, bagasse powder was first treated with 10% H₂SO₄ for 2 hours at room temperature (30-35°C), washed with distilled water and dried. Again the above acid treated bagasse was treated with 5% NaOH for 10 minutes at room temperature, washed and dried. The treated bagasse was taken up for the growth studies of *Cellulomonas culture* (Fig. 1).

4. Combined Effect of Sodium Hydroxide, Steaming and high pressure heat treatment.

1. Bagasse powder was steamed with 5% NaOH solution for 30 minutes
2. Bagasse powder, pretreated with 5% NaOH solution, was subjected to 15 lbs/sq. in. pressure for 15 minutes. The samples were washed, dried in oven and taken up for growth studies (Fig. 4, 5 & 6)

5. Ammonium Hydroxide, 3.75 and 7.5%

Bagasse powder was treated with 3.75% or 7.5% NH₄OH solution for 20 hours or 68 hours respectively at room temperature. The samples were washed, dried and taken up for growth studies (Fig. 4, 5 & 6)

6. Effect of Steaming

1. Bagasse powder was steamed for 1 hour
2. Bagasse powder was soaked in water overnight and then steamed for 1 hour.
3. Bagasse powder was soaked in 10% NaOH for 10 minutes, washed and then steamed for 1 hour.

All the treated samples were washed, dried in oven and taken up for growth studies (Table-2)

7. Treatment of fibre and pith portion of bagasse

Fibre and pith were separated by a stream

of water¹³ and dried in oven. Fibre and pith protions were separately treated with 5% NaOH for 10 minutes at room temperature, washed and dried in oven. They were further taken up for growth studies. (Table- 3)

Results and Discussion

Ordinary untreated bagasse seemed to be resistant to bacterial attack. Grinding of bagasse increased the bacterial activity. A 65 mesh size powdered bagasse gave good results. The culture isolated from Rumen and Bioliquid showed good cellulolytic power in the utilization of bagasse and gave rise to sufficient biomass. The activities of these cultures were comparable to the standard strain of *Cellulomonas fimi*, 12108 (obtained from IAM culture collection, Japan). Treatment of bagasse with 5% NaOH for 5 minutes and 10 minutes and 1% H_2SO_4 for 2 hours showed good results on Rumen and Bioliquid cultures (Fig. 2 & 3). But 10% H_2SO_4 treatment for 2 hour at room temperature was suitable only for *Cellulomonas* culture (Fig. 1) Treatment of bagasse with different concentrations of mamonia was of little value for microbial attack (Fig. 4, 5 & 6), Steaming and pressure cooking combined with alkali treatment improved cellulose utilization, (Fig. 4, 5 & 6). Higher concentration of alkali (10% NaOH) had inhibitory effect on the growth of the cultures. 10% H_2SO_4 had an inhibitory effect on Rumen and Bioliquid culture but had good effect on *Cellulomonas* culture. Treatment period beyond 10 minutes and 2 hours with NaOH and H_2SO_4 showed inhibitory effect on the growth of the cultures.

The separation of bagasse into fibre and pith did not cause much difference in the bacterial activity. Treated pith was better than treated fibre though Bioliquid culture showed good activity in both i. e. fibre and pith protions.

Unwashed bagasse contained spore forming bacteria which were eliminated with great difficulty. This agrees with the work of Callihan *et al*¹⁴. Several types of microprganisms interfere in cellulose fermentation and decrease the cellulolytic activity of the cultures. Thorough washing and sterilization of the material helped in removing contamination and cellulose fermentation. Grinding of bagasse increased the surface area and helped in the bacterial attack on the substrate. Grinding the bagasse below 65 mesh was not of much significance in microbial growth of the cultures tried, though there are some reports of the use of 2 mm size for better growth¹⁵.

Presence of lignin¹⁶ and hemicellulose in bagasse decreased cellulolytic activity. Treatment of bagasse with different concentrations of acid and alkali helped in removing hemicellulose and lignin¹¹. Combination of acid and alkali treatment helps in purifying the cellulose part of bagasse and makes it more susceptible for bacterial attack. Similar views have been expressed by Han and Callihan¹¹.

Steaming and pressure cooking in combination with alkali is reported to help in the removal of hemicellulose structures, disruption of lignin structure, hydration, swelling of the cellulose and decreased cellulose crystallinity¹⁶. Strong alkali (10% NaOH) and acid (10% H_2SO_4) treatment leaves some

inhibitory substance which prevents rapid attack by the enzymes. This may be the reason for low turbidity readings as seen in Table—1 and Fig. 2 & 3.

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Effect of 10% Sodium Hydroxide Treatment of Bagasse on the Growth of Cultures

Table-I

Time in hrs.	Turbidity — Klett Readings (Net Increase)					
	Cellulomonas Culture		Rumen Culture		Bioliqid Culture	
	Time of treatment 5 min. 10 min. 2 hrs.		Time of treatment 5 min. 10 min. 2 hrs.		Time of treatment 5 min. 10 min. 2 hrs.	
24	50	50	50	80	80	40
48	55	60	60	65	90	75
72	65	60	70	70	105	95
96	70	60	90	75	110	105

Effect of Steaming of Bagasse on the Growth of Cultures

Table—2

Turbidity — Klett Readings (Net Increase)									
Cellulomonas Culture					Rumen Culture			Bioliquid Culture	
Time in hrs.	Cellulomonas Culture				Rumen Culture			Bioliquid Culture	
	Control 5% NaOH 10 min.	Steamed for 1 hr.	Soaked in water + Steamed 1 hr.	Soaked in Alkali + Steam 1 hr.	Control 5% NaOH 10 min.	Steamed for 1 hr.	Soaked in water + Steamed 1 hr.	Soaked in Alkali + Steamed 1 hr.	Control 5% NaOH 10 min.
24	40	55	55	55	55	50	40	40	50
48	95	113	87	70	110	88	73	80	85
72	60	100	95	74	80	120	112	116	143
96	60	90	85	65	80	80	80	90	115

Effect of 5% NaOH, 10 Min. Treatment of Fibre & Pith on the Growth of the Cultures

Table-3

Turbidity - Klett Readings (Net Increase)

Time in hrs.	Cellulomonas Culture				Rumen Culture				Bioliquid Culture			
	Pith		Fibre		Pith		Fibre		Pith		Fibre	
	Treated	Not treat- ed	Treated	Not treated	Treat- ed	Not treated	Treat- ed	Not treated	Treated	Not treated	Treated	Not treated
24	50	45	35	35	50	50	50	40	45	50	50	50
48	100	75	65	50	85	70	75	60	90	85	100	85
72	100	70	65	50	85	70	75	60	90	85	100	85
96	90	70	65	50	70	60	60	50	85	80	95	75

EFFECT OF NaOH & H_2SO_4 TREATMENTS OF BAGASSE ON THE GROWTH OF CELLULOMONAS CULTURE

- 1 5% NaOH 5 Min
- 2 " " 10 "
- 3 " " 2 Hr
- 4 1% H_2SO_4 2 Hr
- 5 " " 20 Hr
- 6 10% " 2 Hr
- 7 1% " " 5% NaOH 10 Min

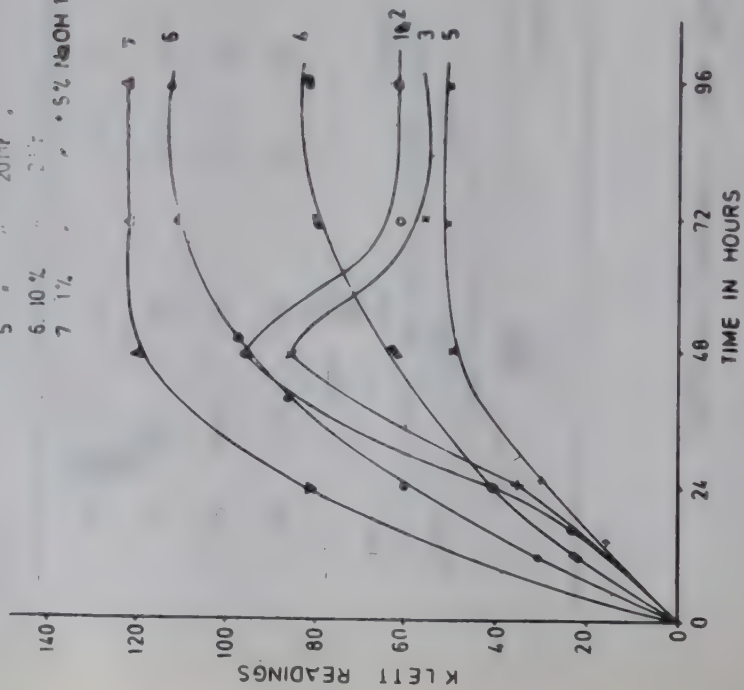


FIG 1

EFFECT OF NaOH & H_2SO_4 TREATMENT OF BAGASSE ON THE GROWTH OF RUMEN CULTURE

- 1 5% NaOH 10 Min
- 2 1% H_2SO_4 2 Hr
- 3 10% " "
- 4 1% " 20 Hr
- 5 5% NaOH 5 Min
- 6 5% " 2 Hr

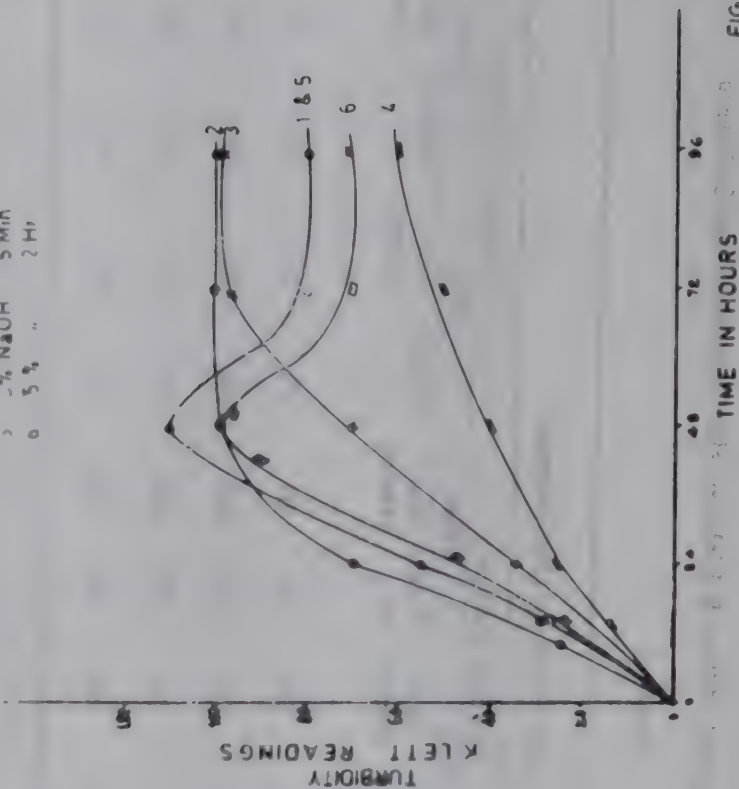


FIG 2

EFFECT OF NaOH & H₂SO₄ TREATMENTS OF BAGASSE ON THE GROWTH OF BIOLIQUID CULTURE

1. 5% NaOH 5 Min
2. " " 10 "
3. " " 2 hr
4. 1% H₂SO₄ 2 hr
5. 1% " 20 hr
6. 10% " 2 hr

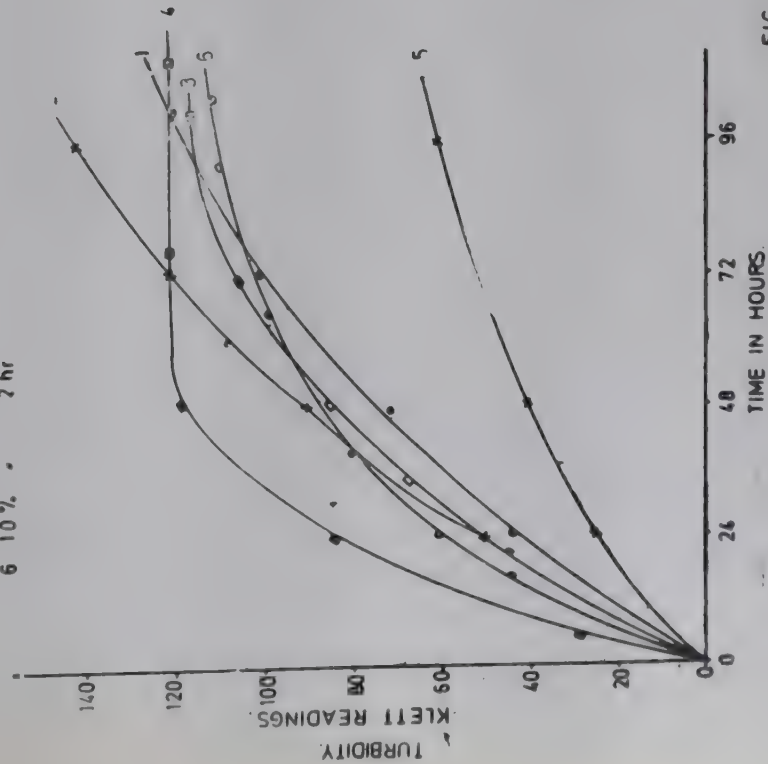


FIG. 3

COMBINED EFFECT OF NaOH-HIGH PRESSURE HEAT TREATMENT & AMMONIA TREATMENT OF BAGASSE ON THE GROWTH OF CELLULOMONAS CULTURE

1. 5% NaOH 10 Min
2. 5% NaOH 30 Min Steaming
3. 5% NaOH 15 lbs/50 in for 15 Min
4. 3% 5% NH₃ 20 hr
5. 3% 5% NH₃ 68 hr
6. 7-5% NH₃ 20 hr
7. 7-5% NH₃ 68 hr

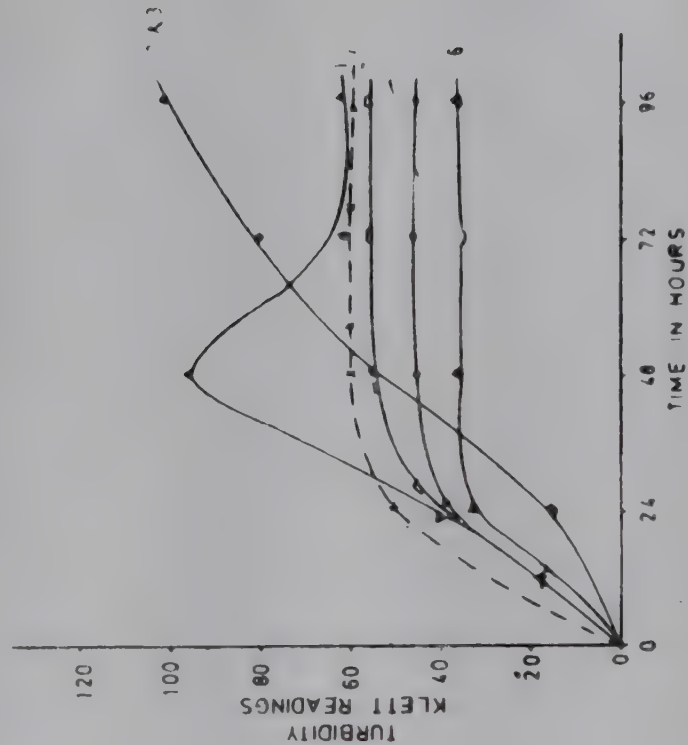


FIG. 3

COMBINED EFFECT OF NaOH-HIGH PRESSURE HEAT
TREATMENT & AMMONIA TREATMENT OF BAGASSE ON
THE GROWTH OF BIO LIQUID CULTURE

5 2 NaOH 10 Mins
2 5 2 NaOH 30 Mins Steaming
3 5 2 NaOH 15 lbs/sq in for 15 Mins
4 37 5 % NH₃ 20 hrs
5 37 5 % NH₃ 68 hrs
6 7 5 % NH₃ 20 hrs

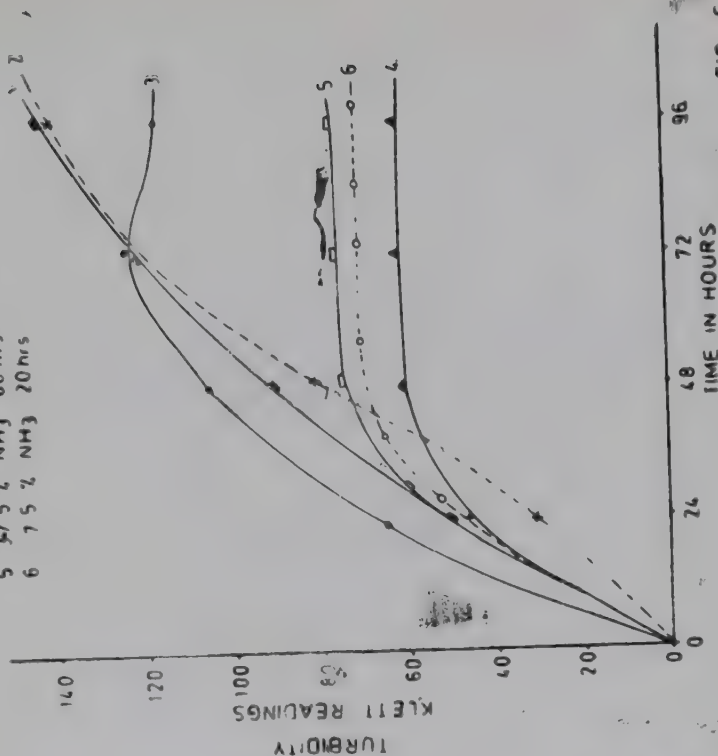


FIG 6

COMBINED EFFECT OF NaOH-HIGH PRESSURE HEAT
TREATMENT & AMMONIA TREATMENT OF BAGASSE ON
THE GROWTH OF RUMEN CULTURE

1 5 2 NaOH 10 Min
2 5 2 NaOH 30 Min Steaming
3 5 2 NaOH 15 lbs/sq in 15 Mins
4 37 5 % NH₃ 20 hr
5 37 5 % NH₃ 68 hr
6 7 5 % NH₃ 20 hr

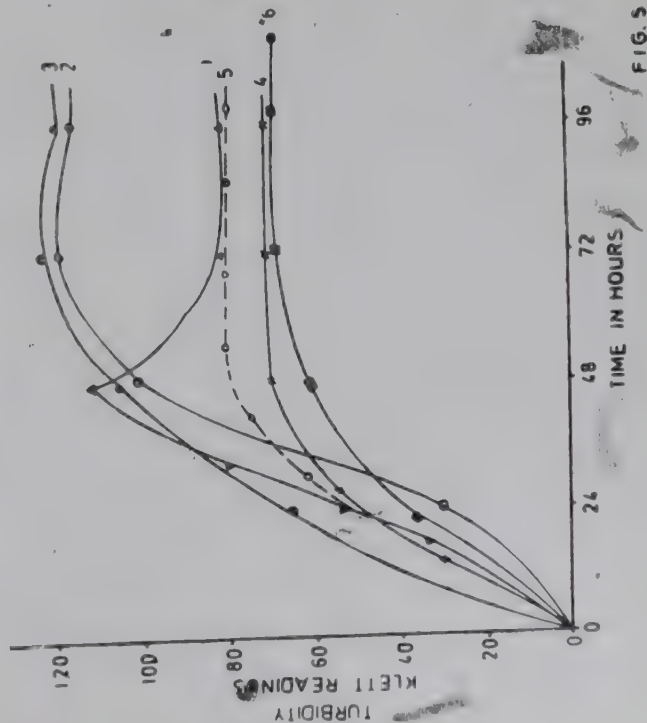


FIG. 5

FURTHER STUDIES ON THE TREATMENT OF AMMONIFIED DISTILLERY WASTE USING AEROBIC PROCESSES TO REDUCE THE B.O.D.

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ABSTRACT

The bacterial ammonification process developed at National Sugar Institute and described earlier reduces the B.O.D. of distillery wastes to about 3000 mg/liter. A number of different aerobic processes were investigated for their ability to reduce the B.O.D of the ammonified distillery waste, of these, Activated Sludge, Modified Aeration, Contact Stabilization, Submerged Filter and Biofilter Techniques were found to be effective. Shallow oxidation ponds were slow and only partially effective. Aerated lagoons were not effective under the experimental conditions used.

Introduction :

The environmental pollution of air, water, and soil is a challenging problem of the modern society. Efforts are constantly being made to check the detrimental effects of pollution. Several methods such as (1) Anaerobic digestion of waste in ponds and closed tanks (2) Ammonification of waste in pukka tanks³, (3) Dilution of distillery waste and using it as irrigation⁴ water, (4) Recovery of potash by evaporation⁵ and incineration of waste have been suggested.

In the previous studies in the laboratories the treatment of distillery waste using ammonifying bacteria have been reported, wherein B.O.D. loads have been reduced from 12000-15000 mg/l to 25000-3000 mg/l in a period of 4-5 days of retention time, corresponding to 75-80% reduction in BOD. The treatment trials were taken up on pilot plant scale and full scale in different distilleries^{3,6}.

The ammonified liquid contained sufficiently high B.O.D and needed about 5 times of its volume of water for dilution before being

discharged for irrigation. So it was necessary to treat the wastes further to reduce this BOD and minimize the water requirement.

Eckenfelder has paid great attention to aerobic processes of treatment of industrial wastes and has suggested several possible modification⁷. In our preliminary studies it was observed that the conventional method of aerobic process as followed in sewage, was not directly applicable to treat ammonified liquid further. So attempts have been made to study the different aerobic processes as proposed by Eckenfelder.

In the present study data on laboratory scale have been collected on following aspects of different aerobic processes to treat the ammonified liquid further and reduce the BOD :- (i) Oxidation ponds, (ii) Aerated lagoons (Surface and submerged aeration), (iii) Extended aeration, (iv) Contact stabilization, (v) Modified aeration, (vi) Activated sludge process and (vii) Submerged filter and biofilter.

Materials and Methods

Estimation of COD and Mixed Liquid Suspended solids (MLSS)

The organic matter content COD and MLSS in samples were estimated by following standard methods of analyses of American Public Health Association⁸.

Estimation of Oxygen Absorption Values

The oxygen absorption values (OA) representing organic matter in samples were esti-

mated as per the methods of analysis of Clowe and Coleman⁹.

Estimation of Formal Nitrogen, Amino Nitrogen and Nitrite Content

The formal nitrogen content in the samples was determined by employing Sorenson's formal titration method¹⁰. Nessler's method and sulfanilic acid with naphthylamine method were used for amino nitrogen and nitrite^{9,11} contents.

Ammonification Process

Ammonifying bacteria was developed from sewage soaked soil over synthetic medium using enrichment culture technique. The bacterial culture was acclimatized towards spent wash for about 10-15 days by slowly increasing the doses of spent wash in synthetic medium. The extent of acclimatization was judged by the lowering in of COD, rise liberation of ammonia. The completely trained and acclimatized culture was used in further experiments.

Diluted sterilized distillery waste of 3.2 to 3.5 Brix was enriched with the addition of urea and superphosphate as nutrients for microorganisms. Diluted spent wash was added to the culture in 2 : 1 ratio (Two parts of spent wash medium per one part of culture) and the culture was developed in carboys for 4 days.

Oxidation Ponds :

The ammonified spent wash was put in shallow basins of 1 to 1.5 ft. depth and left

for about three weeks at 32°-35°C for self oxidation. The contents were analysed for OA, COD, BOD, nitrite and ammonia after three weeks time (Table-2).

Aerated lagoons :

In the study of aerated lagoons, the ammonified spent wash was taken in deep basins of 2.5 to 3 ft. depth. Surface aeration and submerged aeration were effected by a low speed stirrer and a high speed stirrer, respectively, located as in Fig. 1. The contents were analysed for COD and OA (Table 3 A & B).

Extended Aeration :

The ammonified culture was aerated with and without suspended matter upto 18 hours and analysed for COD and OA at regular intervals (Table 4 A & B).

Modified Aeration :

A known amount of sewage sludge was aerated with a fresh feed of ammonified liquid for 24 to 48 hrs¹ and sent to a clarifier. The settled sludge was recycled back to the aerator and aerated again and analysed for COD and OA at regular intervals (Table-5)

Contact Estabilization :

Acclimatized spent wash sludge was kept in contact with ammonified liquid for 1, 2 or 16 hrs. in different experiments and then aerated for 4 to 6 hrs. The contents were then sent to a clarifier and the settled sludge was recycled through the stabilizer (Table-6 & Fig. 2).

Completely Mixed Activated Sludge :

Activated sludge acclimatized to ammonified liquid (treated distillery spent wash) prepared by aeration of sewage soaked soil with small regular increasing doses of ammonified liquid. The settled sludge solids were removed by sedimentation after 6-8 hrs. of aeration, mixed with fresh ammonified liquid and again aerated. The settleable material was removed in a clarifier and every time about 10% of settled sludge was returned separately to the main aerator. Data are given for OA and COD reduction in 6-8 hrs. of aeration, mixed with fresh ammonified liquid and again aerated. The settleable material was removed in a clarifier and every time about 10% of settled sludge was returned separately to the main aerator. Data are given for OA and COD reduction in 6-8 hrs. of aeration period (Table-7 & Fig. 3).

Submerged Filter :

A 10 litres capacity aspirator bottle was filled with 1 to 1.5" size brick pieces to get about 1 ft height of brick layer in the bottle.

- (a) The bottle was filled up with ammonified spent wash to a level just sufficient to keep the brick pieces in submerged state. The contents were aerated for 48 hours at 22°C.
- (b) The brick layers were treated by giving 500 ml acclimatized sludge, before filling with ammonified spent wash. It was then aerated for 24 hrs. (Table-6 A & B).

Biofilter :

For biofiltration studies a small laboratory bio-filter was constructed by using a corning

tubing of 2.5" size dia and 4.5' height. The tube was filled with $\frac{1}{2}$ " size brick pieces and activated by acclimatized ammonified sludge culture by recycling of the liquid 3 to 4 times a day. The activity of the bed was determined by analysing the contents for OA and COD before and after passing through the bed. When the bed gained some activity after about 4 weeks' time, it was taken up for treatment trials. The ammonified liquid having 11,000 to 14,000 mg/l COD was treated in the bio-filter by trickling the liquid on the bed at the rate of 1 to 2 litre/hr. The reduction obtained in 4 recycles is reported (Table-9 & Fig-4).

Results

Ammonifying bacteria, while utilizing the nitrogenous compounds of the waste, decompose the organic carbon compounds and reduce the BOD of the waste. In a period of about 4 days, a 75-76% reduction in BOD is obtained (Table-1A). No further reduction in BOD was obtained by increasing the retention time. The characteristics of raw and treated spent wash are compared in Table-1 B.

Ammonified liquid kept in shallow basins exhibited about 37% reduction in BOD in about 3 weeks time (Table-2). Aerated lagoons with surface or submerged aeration did not bring about any reduction in OA or COD (Table 3 A & B).

Extended aeration process upto 48 hours without added sludge did not show any reduction in COD was obtained in 48 hours time (Table 4 B).

Modified aeration, with addition of sewage sludge and aeration for 24 hrs. gave 5% reduction in COD and BOD (Table-5). The hourly contact of sludge with ammonified effluent prior to aeration gave good results showing about 50% reduction. Further increase in contact time was not of much significance (Table-6).

Completely mixed activated sludge process was able to show 50% reduction in 6 to 8 hrs. of aeration (Table-7).

Aeration to submerged filter technique for ammonified liquid did not show any result unless sludge was added to the filter. With the addition of sludge, 10-12% COD reduction was obtained in 48 hrs. (Table 8 B). Biofilter took a long time to get activated and showed 27-32% reduction in COD in a period of 6-8 hrs. with a 4 cycle operation (Table-9).

Discussion

The Ammonifying bacteria as employed in the treatment of distillery waste are anaerobic¹². The culture got inactivated by aeration in alkaline conditions, and the cells were disrupted. Prolonged aeration resulted in rise in pH and alkalinity of the waste, and also rise in COD was noticed, possibly, due to the resolubilization of cellular material⁷. Thus aeration without added sludge did not help in COD or BOD removal. This can be seen from Table 4 A. There was no further reduction in BOD when ammonified treated waste was freed off of suspended solids and microbial cells by centrifugation. Extended aeration of this liquid also did not show any signs of BOD reduction.

Ammonified liquid exposed to atmosphere in shallow basins showed COD and BOD reduction, increase in nitrite and decrease in ammonia content, showing some nitrification activity (Table-2). The period required was about three weeks.

According to Eckenfelder the F/M ratio (Food to microorganism) has to be reduced while aerating in aerobic lagoons, F/M ratio can be reduced by increasing suspended solids or MLVSS (Mixed liquid volatile suspended solids) obtained by sedimentation of effluent in prior reactions or by additions of sewage sludge^{7,14}. Addition of acclimatized sludge or activated sewage sludge helped in the removal of BOD from the ammonified wash.

The lowering of BOD by Contact stabilization technique suggested that some induced enzymes are produced by sludge in 1 to 2 hrs. Contact stabilization is generally recommended in cases of effluents having soluble BOD^{15,16}.

Young, Bauman and Wall¹⁷ have reported that during further treatment of secondary effluent (such as ammonified effluent) nitrification occurs while using trickling filters, submerged filters or packed bed reactors¹⁴. Submerged filters and biofilters showed some reduction in COD, on addition of suspended sludge, which helped in the process of nitrification of the waste (Tables 8 B & 9).

Acknowledgements

The authors' thanks are due to Dr. N. A. Ramaiah, Director, National Sugar Institute, Kanpur, and Dr. L. Viswanathan, Professor of Biochemistry, National Sugar Institute, Kanpur for taking interest in the work. One of us (C.B.A.) wishes to thank the Bazpur Distillery authorities, Bazpur, and Managing Director and Technical Advisor, U. P. Co-operative Sugar Factories Federation Limited, Lucknow for giving encouragement in the research work.

Table—1-A

Treatment of Distillery Waste by Ammonification Process Performance of Ammonifying Culture :

Particulars	Time in hours					% Reduction in 96 hrs.
	0	24	48	72	96	
O A mg/l	11100	7200	5907	4000	2790	74.9
COD „	32320	21130	20301	17819	14000	56.7
BOD „	12500	10000	7055	3750	3000	76.0

Table—1-B**Characteristics of Raw Spent Wash and of Spent Wash Treated by Ammonification Process.**

Sl. No.	Particulars	Raw spent wash	Treated spent wash
1.	Colour	Reddish brown	Brownish black
2.	pH	4.0 to 4.8	7.8 to 8.8
3.	Smell	Caramel	Ammoniacal
4.	Total Solids (mg/l)	1,03,000 to 1,10,000	20,000 to 22,000
5.	Volatile solids (mg/l)	65,000	7,000 to 8,000
6.	Ash (mg/l)	34,000 to 41,000	11,000 to 14,000
7.	Total Nitrogen (mg/l)	1,200 to 1,500	560 to 600
8.	Ammonical Nitrogen (mg/l)	70	480 to 560
9.	Phosphate as P_2O_5 (mg/l)	250 to 370	115 to 150
10.	Potash as K_2O (mg/l)	8,000 to 10,000	2,500 to 3,500
11.	OA Oxygen absorbed (mg/l)	36,000 to 88,000	2,790 to 3,460
12.	COD, Chemical Oxygen demand (mg/l)	38,000 to 1,24,000	9,000 to 10,200
13.	BCD, Biological oxygen demand (mg/l)	30,000 to 45,000	2,500 to 3,200

Table—2

Treatment of Ammonified Effluent by Oxidation Ponds

Particulars		Initial	Final	% Reduction in 3 weeks.
OA	mg/l	3618	1893	47.7
COD	mg/l	11100	6600	40.5
BOD	mg/l	3204	2004	37.5
Nitrite	mg/l	57	140	—
Ammonia	mg/l	514	399	—

Table - 3

Treatment of Ammonified Effluent by Aerated Lagoons

Aeration time in hours	pH	OA mg/l	COD mg/l	% Reduction
A — Surface aeration.				
0	7.8	2886	10101	Nil
8	8.1	2886	10101	Nil
16	8.2	2881	10083	Nil
24	8.2	2831	10083	Nil
48	8.2	2881	10101	Nil
72	8.2	2886	10083	Nil

B— Submergen Aeration

Aeration Time in hours	pH	OA mg/l	GOD mg/l	% Reduction
0	7.8	3215	11152	Nil
8	8.1	3210	11252	Nil
16	8.2	3215	11235	Nil
24	8.2	3210	11235	Nil
48	8.2	3215	11235	Nil
72	8.2	3210	11235	Nil

Table-4**Treatment of Ammocified Effluent by Extended Aeration Process.**

Aeration time in hours	pH	OA mg/l	COD mg/l	% Reduction
A — Ammonified liquid without suspended sludge.				
0	7.8	3265	11427	Nil
8	8.1	3265	11630	Nil
16	8.2	3323	13860	Nil
24	8.2	3323	11865	Nil
36	8.1	3265	11697	Nil
48	8.1	3265	11970	Nil

B. Ammonified liquid with addition of suspended sludge.

Time in hours	pH	OA mg/l	COD mg/l	%Reduction in COD
0	8.3	4459	15606	—
8	8.3	4000	14000	10.3
16	3.3	3750	13125	15.9
24	8.2	3619	12966	16.9
36	8.2	3316	12658	18.9
48	8.2	3300	12648	19.0

Table—5.**Treatment of Ammonified Effluent by Modified Aeration Process**

Time of Aeration in hours	%Reduction in OA	%Reduction in COD	%Reduction in BOD	mg. N. consumed per 100 ml
24	52.9	49.6	48.2	—
36	60.0	61.1	57.5	60.0
48	73.6	69.2	66.8	78.4

Table-6**Treatment of Ammonified Effluent by Contact Stabilization Process****Aeration time 5 hours.**

Contact time in hours	pH		OA mg/C		COD mg/l		%Reduction	
	Initial	Final	Initial	Final	Initial	Final	in OA	In COD
0	7.5	7.8	2886	2461	10191	8210	14.7	19.4
1	7.5	7.8	2886	2061	10191	7213	28.6	29.2
2	7.5	7.8	2474	1243	8411	4216	49.8	49.9
8	7.5	7.8	2850	1368	9975	4514	52.0	54.8
16	7.5	7.8	2850	1362	9975	4630	52.2	53.6

Table-7**Treatment of Ammonified Effluent by Activated Sludge Process****(Completely mixed)**

Time of aeration in hours	OA mg/l		COD mg/l		BOD mg/l		%Reduction		
	Initial	Final	Initial	Final	Initial	Final	OA	COD	BOD
6	4122	2750	22344	11424	5125	3016	33.3	48.9	41.9
8	4937	2587	17270	8533	6016	2898	47.6	50.6	51.8

Table - 8

Treatment of Ammonified Effluent by Submerged Filter Process

Time of aeration in hours	pH	OA mg/l	COD mg/l	% Reduction in COD
A. Without Sludge				
0	8.2	3065	10727	Nil
8	8.2	3072	10700	Nil
16	8.3	3000	10688	Nil
24	8.3	3025	10745	Nil
48	8.3	3072	10748	Nil
B. With Sludge				
Time of aeration in hours	pH	OA mg/l	COD mg/l	% Reduction in COD
0	8.2	3261	11413	—
8	8.3	2978	10720	6.1
16	8.3	2844	9966	12.7
24	8.3	2850	9944	12.9
48	8.3	2865	10027	12.1

Table-9

Treatment of Ammonified Effluent by Biofilter Process

(4 cycles of 6 8 hours each)

S. No.	pH		OA mg/l		COD mg/l		% Reduction in	
	Initial	Final	Initial	Final	Initial	Final	OA	COD
1.	5	7.8	3200	2262	11200	8143	29.3	27.3
2.	7.5	7.8	3600	2368	12600	8524	34.2	32.4
3.	7.5	7.8	4378	2766	14885	9982	36.8	32.9

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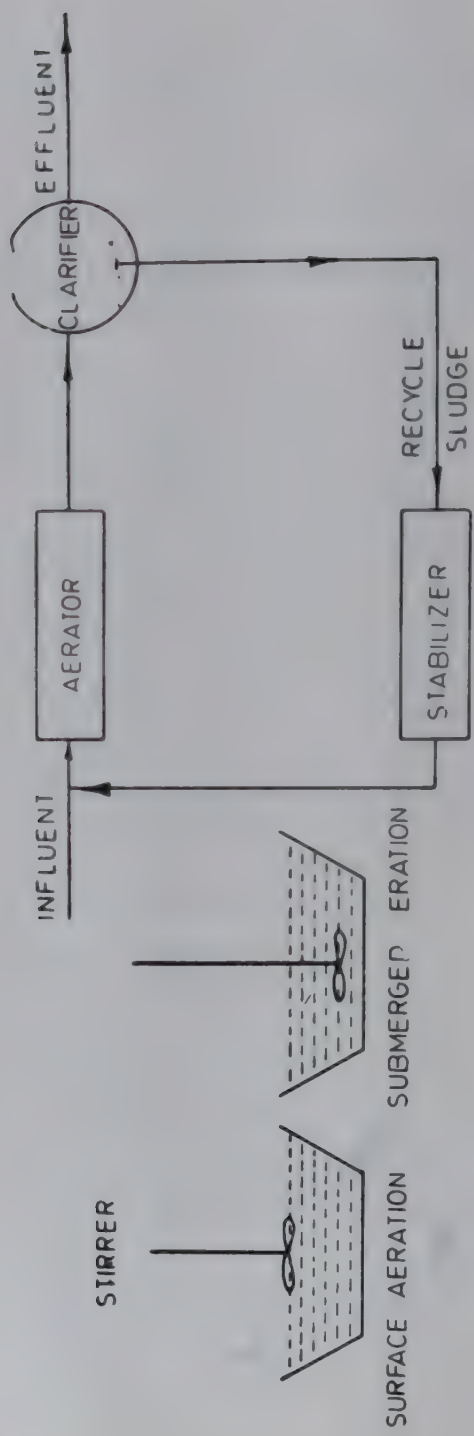


FIG 1 _RATED LAGOONS

FIG 2 CONTACT STABILIZATION

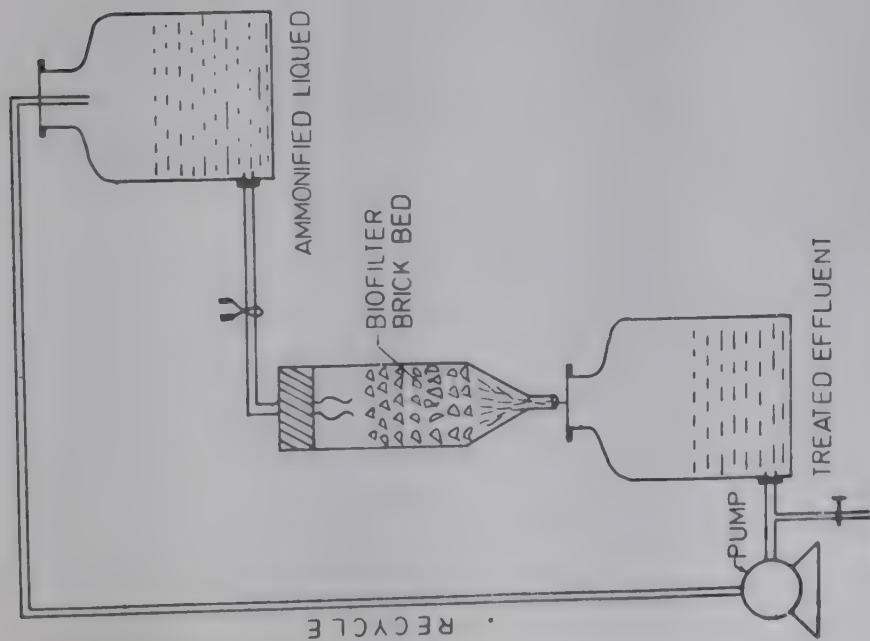


FIG. 4. . BIOFILTER.

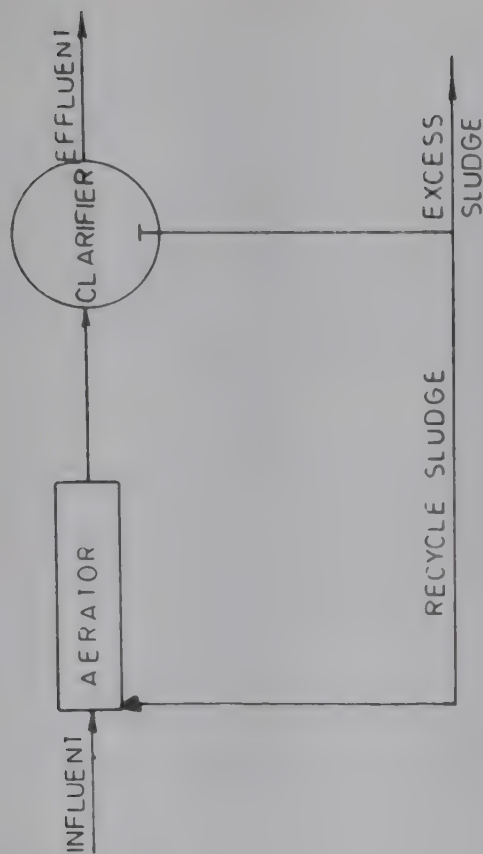


FIG 3 COMPLETELY MIXED ACTIVATED SLUDGE

STUDIES ON FERMENTATION OF MOLASSES AND ITS CHECK UP AT BALRAMPUR.

By

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ABSTRACT

- (a) *Cold water spraying on the sides of the steel tanks.*
- (b) *Recirculating the molasses back into the tank through a pump & spraying it to loose some heat.*
- (c) *Addition of 1 ml of Turkey Red Oil per 100 ml of molasses to control frothing.*
- (d) *Addition of Turkey Red Oil in the Molasses @ 1/2 ml per 100 ml to check/retard the chain reaction in molasses.*

Introduction

Problem of Froth fermentation in Molasses is being experienced in this factory for the last 2 years. During the season 1976-77 the Factory stopped its cane crushing operations in the first week of April but within a week of the closure of the Factory, one Steel Tank containing full of Molasses showed spontaneous combustion of its Molasses. It was reported in the night that the tank was quite hot and on the spot verification it was observed that the tank had been emitting heat to such an extent that one could feel it very easily from a

distance of 15 feet away from it. The Molasses had to be taken out into Katcha pits to prevent its charring up and cake formation and to prevent the steel tank from damage.

This year again the very phenomenon started during the third week of April. It was noted a little earlier that the temperature of the molasses in one steel tank is shooting up to 60-70°C. Precautionary measures were taken to lower down the temperature of the Molasses by recirculating it back into the tank through a pump. Also, arrangements were made to cool down the tank by sprinkling water from

its sides through hose pipe. Simultaneously the matter was referred to the Director, National Sugar Institute, Kanpur to investigate the cause of such happening.

Thus the efforts prevented the final charring of Molasses but the reactions went on. It was slightly retarded by these efforts and the expeditious despatches of Molasses from this tank were carried out. The above noted situation made us to study the problem in further details on the guidance given by Dr. S. K. D. Agarwal of the National Sugar Institute, Kanpur who advised the use of Turkey Red Oil to retard the progress of fermentation.

Partments

The whole experiment is divided into 3 parts consisting of

(a) Molasses manufactured during January/February stored in pucca Pit.

(b) The Molasses being manufactured during April/May when the 'A', 'B' add 'C' Massecuites were boiled at $\pm 23''$ vacuum.

(c) Molasses from 'C' Massecuite boiled at $25''$ vacuum during April/May; while the parents massecuites i. e. 'B' & 'A' were boiled at $23''$ vacuum. Further these 3 categories of Molasses were analysed for seeing the tendency of frothing and its check up.

(a) Mechanical Control

(I) Molasses Frothing was checked by mechanical means i. e. providing one perforated water coil around the steel tank at its top portion of (40' dia. x 25" high). The coil is

1½" in dia. having 1/8" perforation at 3" pitch installed in such a way that the perforations are towards the tank. Cold water was pumped through these coil spraying water on all the sides of the tank and its top portion. This kept the tank fully drenched with water on its side walls.

(II) The Molasses was recirculated back into the tank through the pump, spraying it on the top layer of the Molasses inside the tank. These two attempts went on for 10-12 days regularly and temperature of the molasses in this tank came down from 70°C to 40°-45°C.

(b) Chemical Control

Another attempt was to check the frothing tendency by addition of Turkey Red Oil into the Molasses stored in this tank which further controlled the frothing tendency. In the Laboratory the observations were carried out as given in Table No. 1 (See Fig. 1).

(B) Experiment for checking the fermenting tendency or to retard it. Different doses of Turkey Red Oil were used and the tendency of sugar destruction was noted by keeping the Molasses at 70°C for long. The observations are given in Table No. 2 to 13 (See fig. 3 to 5).

Results

1st. Set (a) When the Molasses was kept at a constant temperature of 70°C for 122 hours froth developed upto 110% of the initial volume without addition of any chemical. But the same showed lower tendency when 1 ml of Turkey Red Oil was used to 200

ml of Molasses. The froth development was reduced to 47.5% increase during the same period. Increasing the doze to 2 ml. of Turkey Red Oil per 200 ml of molasses, the froth increase was noticed only 15% to the initial volume.

2nd Set (b) The above results were repeated in a second observation of the molasses stored in another tank and the results were 112.5%. Froth increase in the froth development without adding any chemical and by keeping the Molasses at 70°C

for 122 hours. The same reduced to 35% when added 1 ml of Turkey Red Oil per 200 ml of Molasses and was only 15% when the Turkey Red Oil doze was doubled.

From Experiment (a) and (b) above it was revealed that the optimum doze of Turkey Red Oil is 1 ml per 200 ml of Molasses approximately for controlling the froth fermentation.

Experiment (A) Pit Molasses stored during January/February 1978 was analysed as reported below –

Brix	90.4%.
Pol.	34.3%.
Purity.	37.94%.
Reducing sugars.	11.93%.
Convertible reducing sugars	36.01%.

Turkey Red Oil was used in dozes 1/4 ml 1/2 ml and 1 ml, 2 ml and 3 ml per 200 ml of molasses and the same was kept for 192 hours at constant temperature of 70°C (See fig. 2 for optimum doze of T. R. O). The observation was that the pol. destruction was 45.77% when the molasses was kept at 70°C for 192 hours without addition of T. R. O. which could be reduced to 22.60% using 1 ml. of T. R. O. per 200 ml. of molasses. Similarly, the purity loss of 50.87% was reduced to the tune of 40.01% and total reducing sugars from 20.07% to 9.55%.

Part The Molasses manufactured from masscuitet boiled at 23" vacuum was treated

on the same pattern as above and the results are that the fermentation was arrested by checking the pol. loss from 82.14% to 67.53%, purity loss from 84.11% to 63.33% and total reducing sugars from 33.95% to 22.23%.

Part (C) Similar experiments were carried out on the Molasses manufactured from the Massecuites when boiled at 25" vacuum (2nd part of the Massecuite boiled 23" vacuum). Chain reaction of the molasses was arrested, resulting pol. loss arrest from 42.59% to 30.25% purity loss from 43.82% to 24.19% and total reducing sugars from 25.13% to 15.51%.

These above 2 experiments part B and C are of interesting nature i. e. a very clear demarcation was observed towards the tendency of froth fermentation in Molasses boiled at 23" vacuum as against its part boiled at 25" vacuum.

The very tendency of pol. destruction set in the Molasses boiled at 23" vacuum is high 82.14%. The pol. destruction was noted during a period 192 hours while the Molasses boiled at 25" vacuum could show a destruction of pol. upto 42.59% only during the same period. Table No. 14 at the end of the observations give the conclusion of the chain

reaction under different conditions and with different control measures for checking it.

These studies are yet very preliminary and further more observations are to be carried out.

Acknowledgment

Our sincere thanks are due to sarvasei C.L. Saraogi, president of the Company who extended us due help and encouragement and permitted to publish the work. Thanks are also due to Mr. Ramesh Agarwal, Lab. chemist for his sincere help in carrying out the experiments.

Table—1

Comparative Studies of foam formation w. r. t. T. R. O. in the Final Molasses (observation at 70°C)

Time in Hrs.	Molasses from Tank No. 1			Molasses from Tank No. 2		
	Foam volume in ml. (initial volume of Molasses is 200 ml)			Foam volume in ml. (initial volume of Molasses is 200 ml)		
	Blank	Molasses + 1 ml T. R. O.	Molasses + 2 ml T. R. O.	Blank	Molasses + 1 cc T. R. O.	Molasses + 2 ml T. R. O.
	[1]	[2]	[3]	[4]	[5]	[6]
1	10 (5)	10 (5)	10 (5)	10 (5.0)	10 (5.0)	15 (7.50)
3	20 (10)	20 (10)	15 (7.5)	20 (10.0)	15 (7.50)	20 (10.0)
7	30 (15)	30 (15)	20 (10.0)	30 (15.0)	20 (10.0)	25 (12.5)
8	35 (17.5)	35 (17.5)	25 (12.5)	40 (20.0)	25 (12.5)	30 (15.0)
10	50 (25)	40 (20)	35 (15.0)	50 (25.0)	30 (15.0)	35 (17.5)
12	55 (27.5)	50 (25)	35 (17.5)	60 (30.0)	35 (17.5)	40 (20.0)
14	70 (35.0)	55 (27.5)	40 (20.0)	70 (35.0)	40 (20.0)	45 (22.5)
16	80 (40.0)	60 (30)	50 (25.0)	75 (37.5)	50 (25.0)	55 (27.5)
18	90 (45.0)	65 (32.5)	55 (27.5)	80 (40.0)	55 (27.5)	60 (30.0)

Contd...

Time in Hrs.	Molasses from Tank No. 1			Molasses from Tank No. 2		
	Foam volume in ml. (initial volume of Molasses is 200 ml)			Foam volume in ml (initial volume of Molasses is 200ml)		
	Blank	Molasses+1 ml T. R. O.	Molasses+2 ml T. R. O.	Brix	Molasses+1 ml T. R. O.	Molasses+2 ml T. R. O.
	[1]	[2]	[3]	[4]	[5]	[6]
20	95 (47.5)	70 (35.0)	60 (30.0)	90 (45.0)	60 (30.0)	65 (32.5)
22	100 (50.0)	75 (37.5)	65 (32.5)	100 (50.0)	70 (35.0)	70 (35.0)
28	110 (55.0)	85 (42.5)	75 (37.5)	150 (75.0)	80 (40.0)	65 (32.5)
38	125 (62.5)	95 (47.5)	80 (40.0)	175 (87.50)	70 (35.0)	60 (30.0)
46	--	--	--	--	--	--
65	175 (87.50)	110 (55)	80 (40.0)	175 (87.50)	60 (30.0)	30 (15.0)
89	200(100.00)	110 (55)	70 (35.0)	210(105.00)	40 (20.0)	30 (15.0)
104	210(105.00)	110 (55)	50 (25.0)	215(107.5)	65 (32.5)	30 (15.0)
122	220(110.00)	95 (47.5)	30 (15.0)	225(112.5)	70 (35.0)	30 (15.0)

Data within the bracket shows increase in the % foam formation in the Final Molasses of Steel Tank No. 1 Tank and No. 2.

Fermentation of Molasses

Table—2
Pit Molasses Analysis at 70°C (Blank)

Time in Hrs.	Brix	Pol.	Purity	R.S.	C. R. S.	T. R. S.
0	90.40	34.30	37.94	11.93	36.01	47.94
24	90.40	33.50 (2.33)	37.01 (2.45)	11.68 (2.10)	35.17 (2.33)	46.85 (2.27)
48	90.30	33.30 (2.92)	36.87 (2.82)	11.68 (2.10)	34.96 (2.92)	46.64 (2.71)
72	91.70 (1.44)	32.20 (6.12)	35.11 (7.46)	11.68 (2.10)	33.81 (6.11)	45.49 (5.11)
96	93.00 (2.88)	30.20 (11.95)	33.55 (11.57)	12.70 (6.45)	31.71 (11.94)	44.41 (7.36)
120	93.80 (3.76)	28.60 (16.62)	30.49 (19.64)	12.70 (6.45)	30.05 (16.55)	42.76 (10.81)
144	95.80 (5.97)	26.10 (23.91)	27.24 (28.20)	14.45 (21.12)	27.40 (23.91)	41.85 (12.70)
168	97.00 (7.30)	22.10 (35.57)	22.78 (39.96)	17.53 (46.94)	23.20 (35.57)	40.73 (15.04)
192	99.80 (10.40)	18.60 (45.77)	18.64 (50.87)	18.79 (57.50)	19.53 (45.77)	38.32 (20.07)

Data within the bracket shows increase or decrease in the % of respective determinations w. r. t. initial readings.

Table -3
Pit Molasses Analysis at 70°C (200 ml Molassas + 1/4 ml T. R. O.)

Time in Hrs.	Brix	Pol.	Purity	R. S.	C. R. S.	T. R. S.
0	90.40	34.30	37.94	11.93	36.01	47.94
24	91.0 (0.66)	33.80 (1.46)	37.14 (2.11)	11.68 (2.10)	35.49 (1.44)	47.17 (1.61)
48	91.50 (1.22)	33.30 (2.92)	36.39 (4.09)	11.68 (2.10)	34.96 (2.92)	46.64 (2.71)
72	91.70 (1.44)	32.40 (5.54)	35.33 (6.88)	11.90 (0.25)	34.02 (5.53)	45.92 (4.21)
96	91.70 (1.44)	30.90 (9.91)	33.69 (11.20)	12.17 (2.01)	32.44 (9.91)	44.61 (6.95)
120	93.80 (3.76)	30.20 (11.95)	32.19 (15.16)	12.89 (8.05)	31.71 (11.94)	44.60 (6.97)
144	96.30 (6.53)	23.60 (31.20)	24.50 (35.42)	17.30 (45.01)	24.78 (31.19)	42.08 (12.22)
168	98.00 (8.41)	20.10 (41.40)	20.51 (45.94)	19.92 (66.97)	21.10 (41.40)	41.02 (14.43)
192	99.80 (10.40)	19.20 (44.02)	19.24 (49.29)	20.03 (67.90)	20.16 (44.02)	40.19 (16.17)

Data within the bracket shows increase or decrease in the % of respective analysis w. r. t. initial readings.

Table --4

Pit Molasses Analysis at 70°C (200 ml Molasses + 1/2 ml T. R. O.)

Time in Hrs.	Brix	Pol	Purity	R. S.	C. R. S.	T. R. S.
0	90.40	34.30	37.94	11.93	36.01	47.94
24	90.40	33.80 (1.46)	37.30 (1.45)	11.68 (2.10)	35.49 (1.44)	47.17 (1.61)
48	92.00 (1.77)	33.80 (1.46)	36.73 (3.19)	11.79 (1.17)	35.49 (1.44)	47.28 (1.38)
72	91.20 (0.88)	32.80 (4.37)	35.96 (5.22)	11.90 (0.25)	34.44 (4.36)	46.34 (3.34)
96	92.70 (2.54)	31.20 (9.04)	34.73 (8.46)	12.34 (3.44)	32.76 (9.03)	45.10 (5.92)
120	93.30 (3.21)	30.20 (11.95)	32.36 (14.71)	12.75 (6.87)	31.71 (11.95)	44.46 (7.26)
144	96.60 (6.86)	27.10 (20.99)	28.05 (26.07)	16.44 (37.80)	28.45 (20.99)	44.89 (6.36)
168	97.00 (7.30)	26.10 (23.91)	26.91 (29.07)	17.07 (43.08)	27.45 (23.74)	44.53 (7.11)
192	98.30 (8.74)	21.60 (37.03)	21.97 (42.09)	19.63 (64.54)	22.68 (37.02)	42.31 (11.74)

Data within the bracket shows increase or decrease in the % of respective determinations with respect to initial readings.

Table—5

Pit Molasses Analysis at 70°C (200 ml Molasses + 1 ml T. R. O.)

Time in Hrs.	Brix	Pol.	Purity	R. S.	C. R. S.	T. R. S.
0	90.40	34.30	37.94	11.93	36.01	47.94
24	90.40	34.10 (0.58)	37.72 (0.58)	11.79 (1.17)	35.80 (0.58)	47.54 (0.73)
48	91.00 (0.66)	33.80 (1.46)	37.14 (2.11)	11.95 (0.17)	35.49 (1.44)	47.44 (1.04)
72	91.70 (1.44)	33.60 (2.04)	36.64 (3.43)	12.46 (4.44)	34.02 (5.53)	46.27 (3.05)
96	92.70 (2.54)	32.20 (6.12)	34.73 (8.46)	12.46 (4.44)	33.81 (6.11)	46.27 (3.48)
120	95.30 (5.42)	32.30 (5.83)	33.89 (10.67)	12.13 (1.68)	33.91 (5.83)	46.04 (3.96)
144	97.30 (7.63)	26.80 (21.87)	27.54 (27.41)	17.53 (46.94)	28.14 (21.86)	45.67 (4.74)
168	96.50 (6.75)	25.10 (26.82)	26.01 (31.44)	18.78 (57.42)	26.36 (26.80)	45.14 (5.84)
192	99.30 (9.85)	22.60 (34.11)	22.76 (40.01)	19.63 (64.54)	23.73 (34.10)	43.36 (9.55)

Data within the bracket shows increase or decrease in the % of respective determinations w. r. t. initial readings.

Table—6
Analysis of Final Molasses when the Massecuite was Boiled at 23" vacuum (Blank)
(observations at 70°C)

Time in Hrs.	Brix	Pol.	Purity	R. S.	C. R. S.	T. R. S.
0	86.6	30.80	35.56	23.80	32.34	56.14
24	88.70 (2.42)	30.10 (1.62)	34.16 (3.94)	21.55 (9.45)	31.81 (1.62)	53.36 (4.95)
48	88.00 (0.69)	29.00 (5.84)	32.95 (7.34)	21.55 (9.45)	30.45 (5.84)	52.00 (7.37)
72	90.20 (4.16)	26.20 (14.94)	29.05 (18.31)	23.69 (0.46)	27.51 (14.94)	51.20 (8.80)
96	90.00 (4.16)	22.70 (26.31)	27.38 (23.00)	26.04 (9.41)	23.83 (26.31)	49.87 (11.27)
120	93.30 (7.74)	21.26 (31.49)	22.72 (36.11)	26.30 (10.50)	22.26 (31.17)	48.56 (13.50)
144	93.30 (7.74)	16.30 (47.08)	17.47 (50.87)	26.30 (10.50)	17.11 (47.22)	43.41 (22.68)
168	95.00 (9.70)	7.0 (77.27)	7.37 (79.27)	30.58 (28.49)	7.35 (77.27)	37.93 (32.44)
192	97.30 (12.36)	5.50 (82.14)	5.65 (84.11)	31.31 (31.55)	5.78 (82.10)	37.09 (33.93)

Data within the bracket shows increase or decrease in the % of respective determinations w. r. t. initial readings.

Table—7

**Analysis of Final Molasses when the Masecuite was Boiled at 23" vacuum (200 ml Molasses + 1/4 ml T.R.O.)
(observations at 70°C)**

Time in Hrs.	Brix	Pol.	Purity	R. S.	C. R. S.	T. R. S.
0	86.6	30.80	35.56	23.80	32.34	56.14
24	89.20 (3.00)	30.30 (1.62)	33.97 (4.47)	23.48 (1.34)	31.81 (1.64)	55.29 (1.51)
48	88.00 (1.62)	29.30 (4.87)	33.29 (6.38)	23.07 (3.24)	30.76 (4.89)	53.83 (4.11)
72	89.50 (3.35)	27.40 (11.04)	30.61 (13.92)	23.69 (0.46)	28.77 (11.04)	52.46 (6.56)
96	90.70 (4.73)	24.70 (19.81)	27.38 (23.00)	24.12 (1.34)	25.93 (19.82)	50.05 (10.85)
120	93.60 (8.08)	22.70 (26.30)	24.25 (33.81)	24.81 (4.24)	23.83 (26.31)	48.64 (13.36)
144	94.30 (8.89)	18.30 (40.58)	19.40 (45.44)	26.30 (10.50)	19.21 (40.60)	45.51 (18.93)
168	95.00 (9.70)	7.50 (75.65)	7.89 (77.81)	30.58 (28.49)	7.88 (75.63)	38.46 (31.49)
192	96.80 (11.78)	6.50 (78.90)	6.71 (81.13)	31.31 (31.55)	6.83 (78.88)	38.14 (32.06)

Data within the bracket shows increase in the % of respective determinations w. r. t. initial readings.

Table - 8

Analysis of Final Molasses when the Massequite was Boiled at 25" vacuum [Blank] [Observations at 70°C].

Time in Hrs.	Brix	Pol.	Purity	RS.	C. R. S.	T. R. S.
0	86.6	30.80	35.56	23.80	32.34	56.14
24	89.00 (3.12)	30.50 (0.97)	34.14 (3.99)	23.27 (2.23)	32.02 (0.99)	55.29 (1.51)
48	88.60 (2.31)	30.10 (2.27)	34.19 (3.85)	23.27 (2 23)	31.60 (2.29)	54.87 (2.26)
72	90.00 (3.93)	27.70 (10.08)	30.78 (13.44)	23.91 (0.46)	29.08 (10.08)	52.99 (5.61)
96	91.70 (5.89)	26.70 (13.38)	27.23 (23.43)	23.91 (0.46)	28.03 (13.39)	51.94 (7.48)
120	93.80 (8.31)	24.20 (21.43)	25.79 (27.47)	24.81 (4.24)	25.41 (21.43)	50.22 (10.55)
144	96.30 (11.20)	18.80 (38.96)	19.52 (44.26)	26.50 (10.50)	19.74 (38.96)	46.04 (17.99)
168	96.80 (11.78)	8.60 (72.08)	8.84 (75.14)	32.07 (34.75)	9.03 (72.08)	41.10 (26.74)
192	97.00 (12.01)	7.50 (75.65)	7.73 (78.26)	32.88 (38.15)	7.88 (75.63)	40.76 (27.40)

Table—9

Analysis of Final Molasses when the Masecuite was Boiled at 23" vacuum [200 ml Molasses + 1 ml T. R. O.]. [observations at 70°C].

Time in Hrs.	Brix.	Pol.	Purity.	R.S.	C. R. S.	T. R. S.
0	86.6	30.80	35.56	23.80	32.34	56.14
24	89.00 (2.77)	30.80	34.60 (2.70)	23.27 (2.23)	32.34	55.61 (0.94)
48	88.70 (2.42)	30.40 (1.30)	34.27 (3.63)	23.27 (2.23)	31.92 (1.30)	55.19 (1.69)
72	91.00 (5.08)	27.70 (10.06)	30.44 (14.40)	23.91 (0.46)	29.08 (10.02)	52.99 (5.61)
96	92.20 (6.47)	26.90 (12.66)	29.17 (17.97)	24.13 (1.39)	28.24 (12.68)	52.37 (6.72)
120	93.30 (7.74)	25.20 (18.18)	27.01 (24.04)	23.91 (0.46)	26.46 (18.18)	50.37 (10.28)
144	94.80 (9.47)	19.80 (35.71)	20.88 (41.28)	26.30 (10.50)	20.79 (35.71)	47.09 (16.12)
168	95.10 (9.82)	13.80 (55.19)	14.51 (59.20)	30.58 (28.49)	14.49 (55.19)	45.07 (19.72)
192	96.60 (11.55)	10.00 (67.53)	13.04 (63.33)	32.88 (38.15)	10.50 (67.53)	43.38 (22.73)

Data within the bracket shows increase or decrease in the % respective determinations w. r. t. initial readings.

Table—10

Analysis of Final Molasses when the Masecuite was Boiled at 25" vacuum (Blank) (Observations at 70°C).

Time in Hrs.	Brix.	Pol.	Purity.	R. S.	C. R. S.	't. R. S.
0	94.90	32.40	34.14	23.48	34.02	57.50
24	95.00 (0.11)	32.20 (0. 62)	33.89 (0.73)	22.28 (5.11)	33.81 (0.62)	56.09 (2.37)
48	95.40 (0.53)	30.70 (5.25)	32.18 (5.74)	31.92 (6.64)	32.23 (5.26)	54.15 (5.74)
72	95.90 (0.95)	29.20 (9.88)	30.44 (10.84)	22.29 (5.07)	30.06 (9.88)	52.35 (8.88)
96	96.20 (1.26)	28.10 (13.27)	29.22 (14.41)	21.80 (7.16)	29.51 (13.26)	51.31 (10.69)
120	96.80 (1.90)	25.80 (20.37)	26.65 (21.94)	23.48	27.09 (20.37)	50.57 (11.98)
144	97.00 (2.21)	19.80 (38.89)	20.04 (41.30)	23.48	20.79 (38.89)	44.27 (22.94)
168	97.00 (2.21)	18.60 (42.59)	19.18 (43.82)	23.48	19.53 (42.59)	43.01 (25.13)

Data within the bracket shows increase or decrease in the % of respective determinations w. r. t. initial readings.

Table--11

Analysis of Final Molasses when the Masseuite was Boiled at 25" vacuum (200 ml Molasses + 1/4ml T. R. O.)
[Observations at 70°C]

Time in Hrs.	Brix.	Pol.	Purity.	R. S.	C. R. S.	T. R. S.
0	94.90	32.40	34.14	23.48	34.02	57.50
24	95.00 [0.11]	32.20 [0.62]	33.89 [0.73]	22.87 [2.60]	33.81 [0.62]	56.68 [1.34]
48	95.90 [1.05]	30.90 [4.63]	32.22 [5.62]	23.27 [0.89]	32.44 [4.64]	55.71 [3.03]
72	96.10 [1.26]	30.20 [6.79]	31.42 [7.97]	22.54 [4.00]	31.71 [6.79]	54.25 [5.57]
96	96.60 [1.79]	29.21 [9.88]	30.22 [11.48]	22.95 [2.26]	30.66 [9.88]	53.61 [6.68]
120	97.00 [2.21]	26.10 [19.44]	26.88 [21.27]	23.48	27.40 [19.46]	50.88 [11.44]
144	97.50 [2.74]	24.00 [25.93]	24.61 [27.91]	22.63 [3.62]	25.20 [25.93]	47.83 [16.74]
168	98.00 [3.27]	22.10 [31.79]	23.06 [32.45]	24.34 [3.66]	23.21 [31.78]	47.56 [17.21]

Data within the bracket shows increase or decrease in the % of respective determinations w. r. t. initial readings.

Table-12

Analysis of Final Molasses when the Massequite was Boiled at 25" vacuum [200 ml Molasses + 1/2 ml T.R. O.]
[Observations at 70°C]

Time in Hrs.	Brix.	Pol.	Purity.	R. S.	C. R. S.	T. R. S.
0	94.90	32.40	34.14	23.48	34.02	57.50
24	94.30 [0.63]	32.20 [0.62]	34.14	22.87 [2.60]	33.81 [0.62]	56.68 [1.34]
48	94.80	30.70 [5.26]	32.39 [5.13]	23.48	32.23 [5.26]	55.71 [3.03]
72	95.40 [0.53]	30.00 [7.41]	31.46 [7.85]	23.59 [0.47]	31.50 [7.41]	55.09 [4.11]
96	95.70 [8.84]	29.90 [7.72]	31.24 [8.49]	22.46 [4.34]	31.39 [7.73]	53.85 [6.26]
120	96.20 [1.37]	26.90 [16.98]	27.96 [18.10]	23.69 [0.89]	28.24 [16.99]	51.93 [9.61]
144	96.80 [2.00]	25.40 [21.60]	26.24 [23.14]	21.60 [8.01]	26.67 [21.60]	48.27 [15.98]
168	97.50 [2.74]	22.30 [31.17]	24.72 [27.59]	24.35 [3.71]	23.42 [31.16]	47.72 [17.94]

Data within the bracket shows increase or decrease in the % of respective determinations w. r. t. initial readings.

TABLE - 13

Analysis of Final Molasses when the Molassesuite was Boiled at 25" vacuum (200 ml Molasses + 1 ml T. R. O.)
 (Observations at 70°C)

Time in Hrs.	Brix.	Pol.	Purity	R. S.	C. R. S.	T. R. S.
0	94.90	32.40	34.14	23.48	34.02	57.50
24	94.00	31.90 [1.54]	33.93 [0.62]	23.48	33.49 [1.56]	56.97 [0.84]
48	94.90	31.20 [2.16]	33.40 [2.17]	23.48	33.28 [2.18]	56.76 [1.20]
72	95.40 [0.53]	30.20 [6.79]	31.65 [7.29]	23.90 [1.79]	31.71 [6.79]	55.19 [3.93]
96	95.80 [0.95]	28.90 [10.80]	30.17 [11.63]	24.29 [0.85]	30.34 [10.82]	54.63 [4.91]
120	96.20 [1.37]	28.00 [13.58]	29.11 [14.73]	23.28 [3.45]	29.40 [13.58]	52.68 [8.30]
144	96.80 [2.00]	25.80 [20.37]	26.65 [21.94]	23.27 [0.89]	27.09 [20.37]	50.36 [12.34]
168	97.00 [2.21]	22.60 [30.25]	25.88 24.19]	24.81 [5.66]	23.73 [30.25]	48.54 [15.51]

Data within the bracket shows increase or decrease in the % of respective determination w. r. t. initial readings.

Table -14. (A)

Pit Molasses Analysis at 70°C

Increase or Destruction in between 0 to 192 Hrs. at 70°C.	Blank.	200 ml Molasses + 1/4 ml T.R.O.	200 ml Molasses + 1/2 ml T.R.O.	200 ml Molasses + 1 ml T.R.O.
Pol.	0-45.77%	0.44.02%	0.37.03 %	0-34.11 %
Purity.	0-50.01%	0-49.29%	0.42.09 %	0- 40.01 %
R. S.	0-57.50%	0-67.90 %	0.64.54%	0-64.54%
T. R. S.	0-20.07%	0- 16.17%	0.11.74%	0-9.55%

(B)

Analysis when the Final Masseccuite was boiled at 23'' Vacuum.
(Observations at 70°C)

Increase or Destruction in between 0 to 192 Hrs.	Blank.	200 ml Molasses + 1/4 ml T.R.O.	200 ml Molasses + 1/2 ml T.R.O.	200 ml Molasses + 1 ml T.R.O.
Pol.	0-82.14%	0-78.90%	0-75.65%	0-67.53%
Purity.	0-84.11%	0-81.13%	0- 78.26%	0-63.33 %
R. S.	0-31.55%	0-31.55%	0-38.15%	0-38.15%
T. R. S.	0-33.93%	0-32.06%	0-27.40%	0-22.73%

(Contd.)

C

**Analysis Final Molasses when the Final Masecuite was boiled at 25''
vacuum. (Observations at 70°C**

Increase or Destruction in between 0—168 Hrs.	Blank.	200 ml Molasses + 1/2 ml T.R.O.	200 ml Molasses + 1/2 ml T.R.O.	200 ml Molasses + 1 ml T. R. O.
Pol.	0—42.59%	0—31.79%	0—31.17%	0—30.25%
Purity.	0—43.82%	0—32.45%	0—27.59%	0—24.19%
R. S.	—	0—3.66%	0—3.71%	0—5.66%
T. R. S.	0—25.13%	0—31.78%	0—16.94%	0—15.51%

COMPARATIVE STUDIES OF FOAM FORMATION W.R.T T.R.O IN THE FINAL MOLASSES

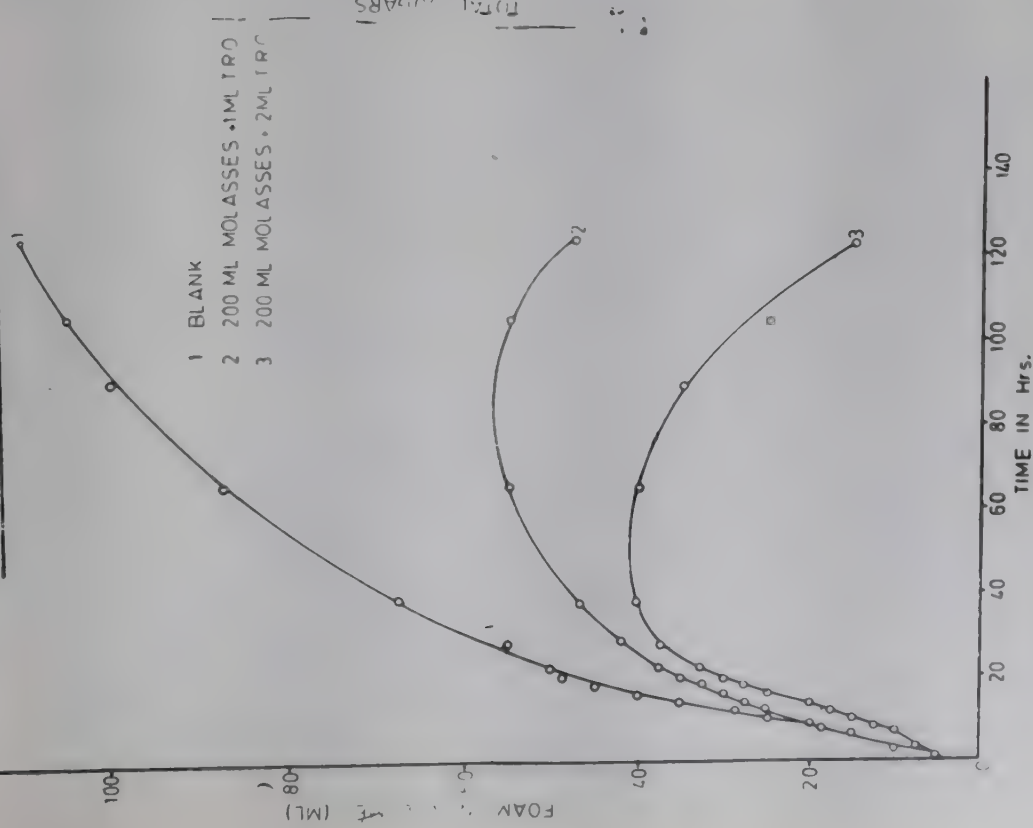


Fig. 1

DETERMINATION OF OPTIMUM DOSE OF T.R.O IN THE FINAL MOLASSES AT 70° C.

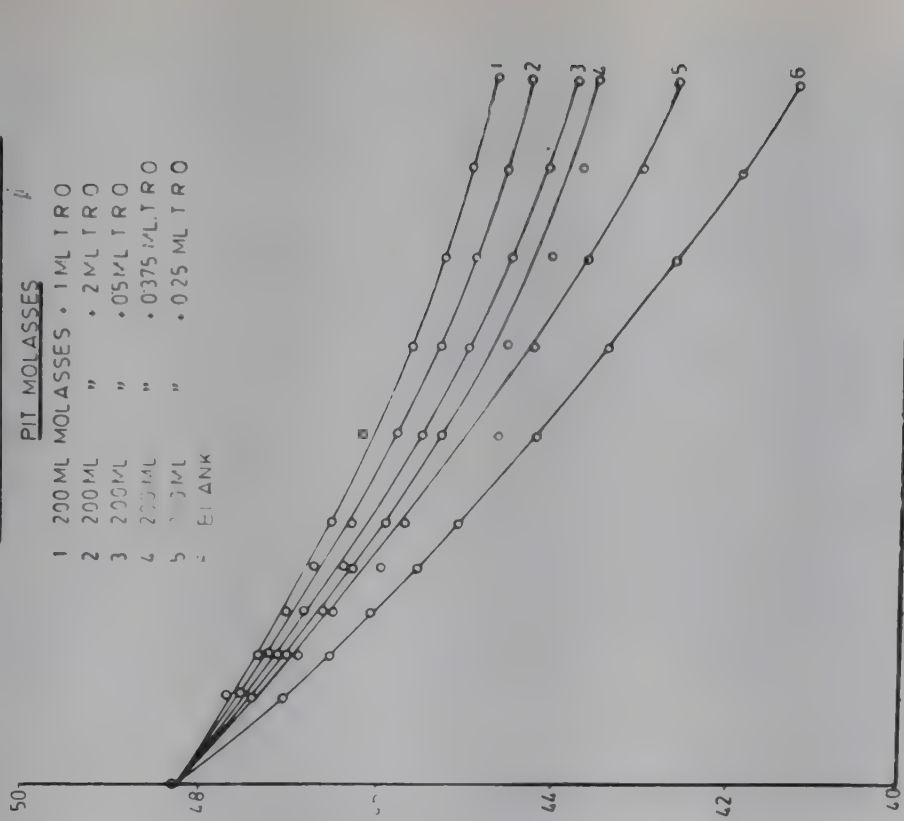


Fig. 2

EFFECT OF DESTRUCTION OF TOTAL SUGARS IN THE FINAL MOLASSES WHEN THE MASSECUITE WAS BOILED AT 25" VACUUM BY ADDITION OF T.R.O. WITH TIME AT 70°C

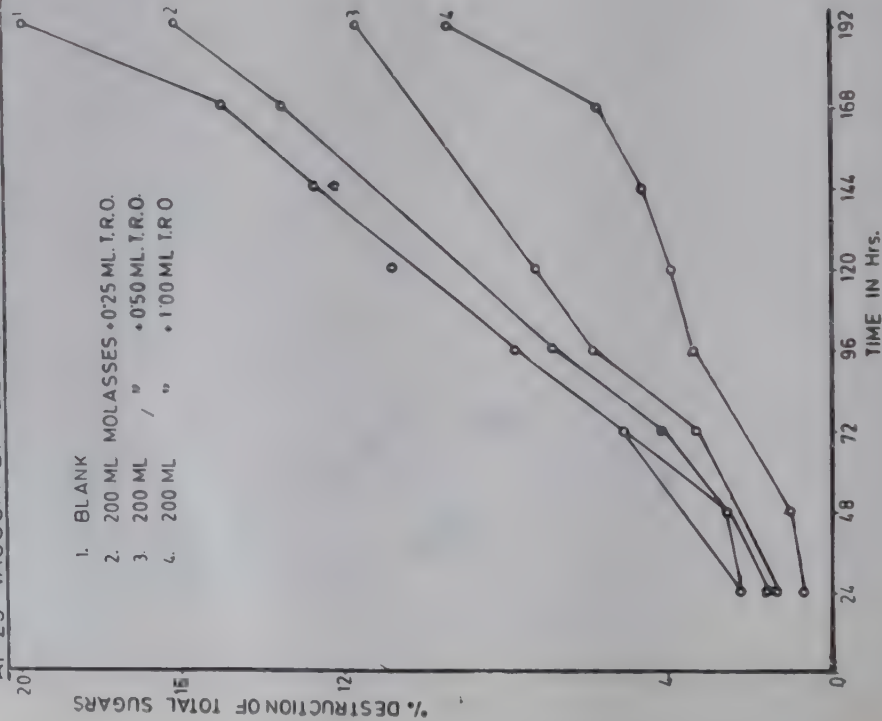


Fig. 3

EFFECT OF DESTRUCTION OF TOTAL SUGARS IN THE FINAL (PIT) MOLASSES BY ADDITION OF T.R.O. WITH TIME AT 70°C

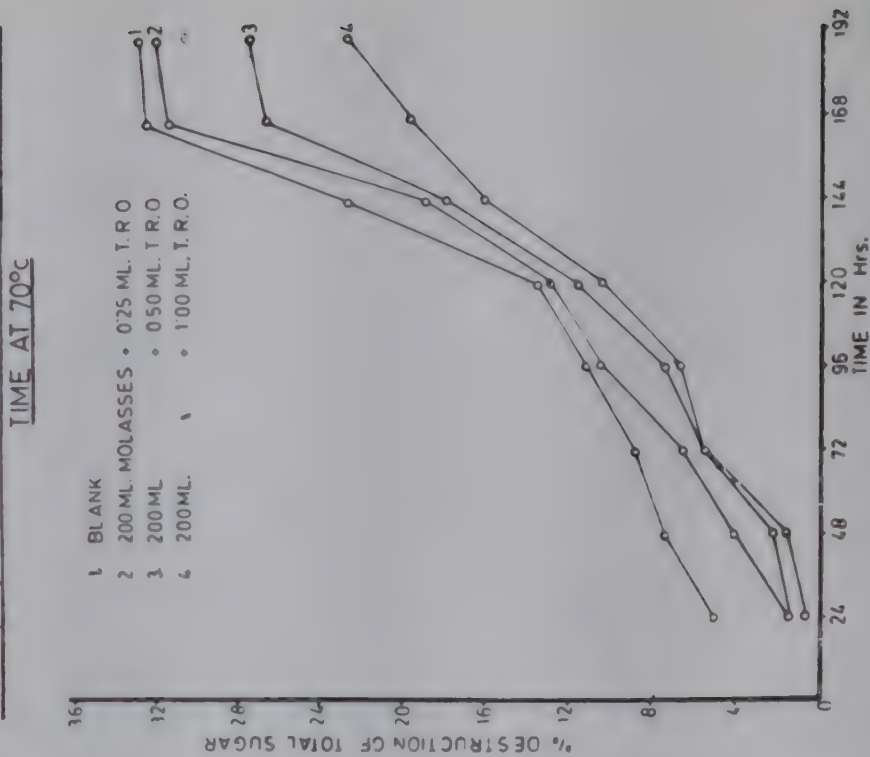


Fig. 4

EFFECT OF DESTRUCTION OF TOTAL SUGARS IN THE
FINAL MOLASSES WHEN THE MASSECUTE WAS BOILED
AT 23" VACUUM OF T.R.O. WITH TIME AT 70°C.

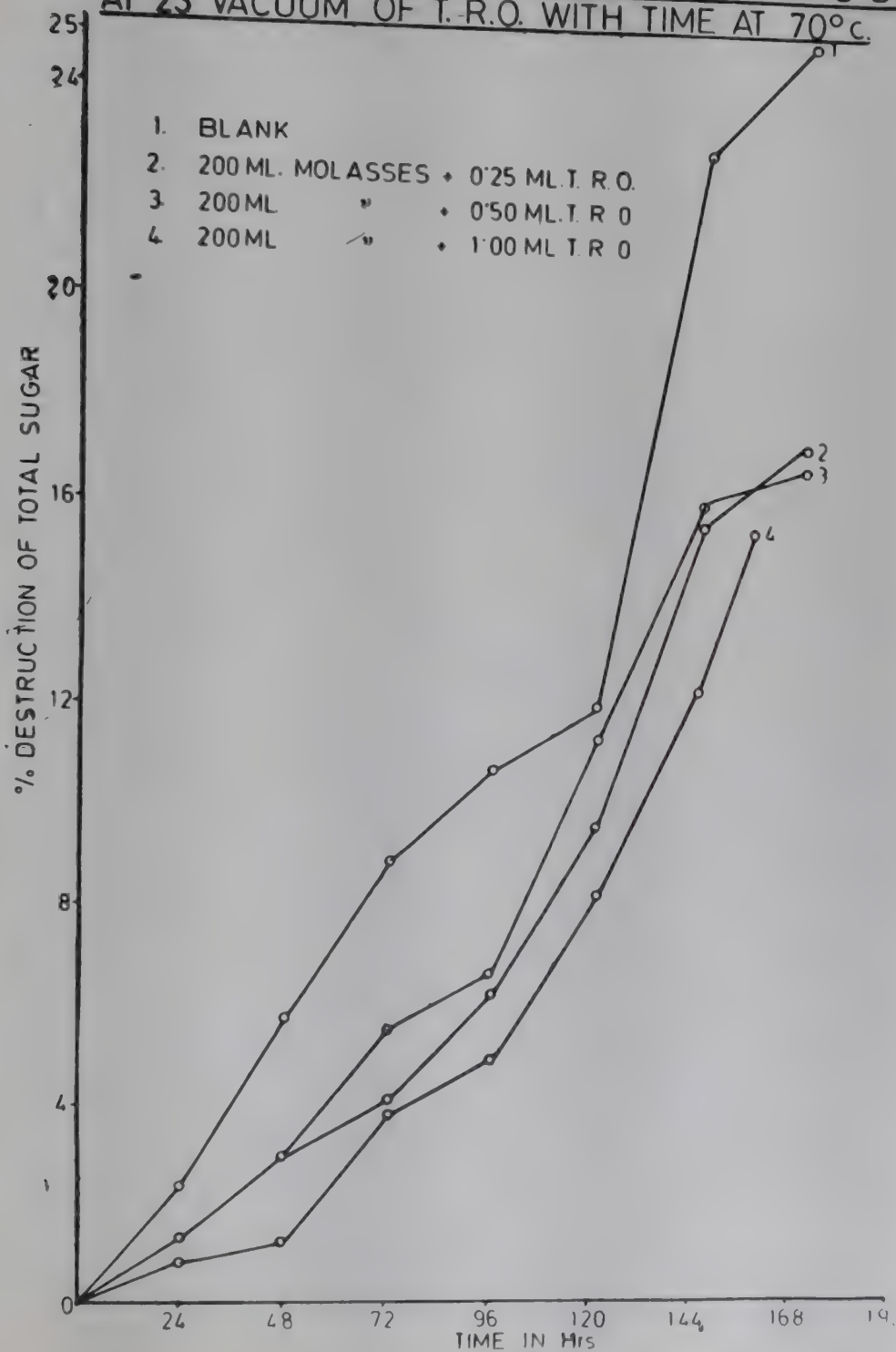


Fig. 5

STUDIES ON BETTER UTILIZATION OF SULPHITATION PRESS MUD

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ABSTRACT

Studies on better utilization of sulphitation press mud revealed that it may be successfully used for the reclamation of saline-alkali soils, for increasing the nutrient content of sugar cane trash compost and for increasing the efficiency of fertilizers producing significantly higher Sugar cane yield. Thus, it is suggested that sulphitation press mud may be better utilized in the manners given above.

Introduction

The manurial value of press mud, specially sulphitation press mud, is well known (Khanna *et al* 1956). But this press mud has been reported to be more suitable for saline alkali soils indicating its ameliorating power for such soils (Dhar, 1935). Siddiqui *et al*, (1974) suggested the use of saw dust for increasing the efficiency of chemical fertilizers in the soils of white sugar belt of North Bihar. The problem of phosphate fixation could be minimised

in calcareous soil by this method. But they did not try press mud, an easily available by-product of sugar industry, for this purpose. The increasing price of fertilizers can be economised by better conservation and utilization of organic wastes. Huge amount of Sugar cane trash is available in the factory reserved areas. This trash can be easily utilized for the preparation of compost. Cowdung is generally used as starter but press mud may also be used for this purpose. A comparative study on this aspect, however, was not carried out.

Thus, the objectives of the present studies were to investigate the role of sulphitation press mud as a reclaiming agent for calcareous saline-alkali soils, its role in improving the nutrient content of sugarcane trash compost and its ability to increase the efficiency of phosphatic fertilizer.

Materials and Methods :

(i) Field trials were conducted for three consecutive years at Pusa Farm to assess the ameliorating power of sulphitation press mud in saline-alkali soil. The soil was calcareous usar land, loam in texture and supported a very poor vegetation.

Thirty cm. high bunds were constructed all around in each sub-plot and drainage channel (90 cm. deep) were dug in between the sub-plot to facilitate percolating water to drainout. The treatment were (a) control (simple leaching) (b) gypsum @ 7.5 Q/ha. (c) FYM @ 200 Q/ha (d) Sulphitation press mud @ 200 Q./ha. Each treatment was replicated four times. The test crop was Sugar cane.

The treatments was given at the time of preparation of the land every year followed by irrigation. Nitrogen @ 70 Kg/ha through urea and P_2O_5 @ 85 Kg/ha through S. S. P. were applied in all the treatment. Sugarcane was grown in first year and third year of the trials. All the fertilizers were applied at the time of planting.

The soil characteristics determined in the original soil samples and thereafter every year

at harvest of sugarcane included pH (1 : 2.5 soil : water ratio), electrical conductivity (saturation extract), total cation exchange capacity, Na-Saturation and total soluble salts by the standard methods as prescribed by Jackson (1958).

(ii) Sugar cane trash was composted with different materials in pits (3 m. x 1.5 m x 1 m) by usual method. The treatments were (1) Sugar cane trash + Cow dung (2) Sugar cane trash + Press mud (carbonation) (3) Sugar cane trash + press mud (carbonation + cow dung) (4) Sugar cane trash + press mud (sulphitation) (5) Sugar cane trash + press mud (sulphitation) + cow dung. Each treatment was replicated four times.

Further studies were carried out to assess the effect of phosphate (SSP) reinforcement on compost prepared from sugar cane trash + press mud. The treatments in this case were (1) Sugar cane trash + press mud (carbonation) + 5 Kg. P_2O_5 / pit (2) Sugar cane trash + press mud (Carbonation) + 7.5 Kg P_2O_5 /pit (3) Sugar cane trash + press mud (carbo) + 10 Kg P_2O_5 / pit. (4) Sugar cane trash + press mud (sulphi) + 5 Kg P_2O_5 / pit (5) Sugar cane trash + press mud (sulphi) + 7.5 Kg P_2O_5 / pit (6) Sugar cane trash + press mud (sulphi) + 10 Kg P_2O_5 / pit. Each treatment was replicated four time.

Estimations of N, P_2O_5 , K_2O and organic carbon were carried out by standard methods as suggested by Jackson (1958).

(iii) Field trials were also conducted to study the effect of sulphitation press mud cane trash compost prepared with sulphitation press mud in increasing the efficiency of phosphatic fertilizer keeping sugar cane as test crop. The treatment were (A) 60 Kg N + 70 Kg P_2O_5 / ha (B) A + 200 Q FYM/ha (C) A + 200 g cane trash compost / ha (D) 200 g FYM / ha (E) 200 g cane trash compost / ha (F) 200 g sulphitation press mud / ha (G) Control. Each treatment was replicated four times.

In the treatments B, C and D chemical fertilizers and organic manures were pre-mixed thoroughly and then applied in the furrows at the time of planting. All the fertilizers were applied at planting time.

Available P_2O_5 in soil was estimated by Olsen's method and in leaf sheat it was estimated colorimetrically after triacid digestion. The sugar cane juice was analysed with the help of polariscope. Khjeldahl's method was followed for N-estimation.

Results and Discussions :

The data of soil characteristics and yield of sugarcane are recorded in Table—I. On the basis of initial pH, electrical conductivity and percentage of Na-saturation in the exchange complex, the soil could be characerised as saline-alkali.

The fall in pH was more rapid in the gypsum treatment. FYM and sulphitation press mud could brought about as good effect as gypsum in the second year onwards. However, control (simple leaching) always showed slightly higher pH.

The Na-saturation was drastically reduced by gypsum (8.6) in the first year itself. This might be due to displacement of exchangeable Na^+ by Ca^{++} of gypsum. The Na-saturation at the end of the first year trial in FYM, sulphitation press mud and control treatments were 14.8%, 18.2% and 24.8% respectively. But in subsequent years the Na-saturation was no doubt lowest in gypsum but sulphitation press mud was almost similar to this followed by FYM treatment. In control plot also the Na-saturation fell below the hazardous level but still it remained doubtful (11.5%) at the end of third year.

The electrical conductivity fell down sharply in the first year and then gradually during the subsequent years which establsilhed at values ranging between 2.3 and 1.8 mmhos / cm. These values are quite safe for growing crops. Hence it may be inferred that all the treatments were able to lower down the electrical conductivity of the soil up to the desired level. The trend of variation of soluble salts in defferent treatment appeared to be more or less similar to that observed in the case of Na-saturation. But the total soluble salts in control and Na-saturation were appreciably higher than other treatments at the end of third year. This indicated the possibility of reversion of soil salinity and alkali inity if only leaching is practiced, This suggested that simple leaching might be effective but the scope for further improvement was apparent for which addition nf soil amendment appeared to be a necessity. Sulphitation press mud did not appear to be inferior as compared to gypsum.

The general yield of sugar cane was quite low in the first year as compared to third year. This was due to the bad effects of salinity and alkalinity which were severe in the first year. In the third year there was marked improvement in the soil characteristic. The treatment wise yield in descending order in the first year was FYM > control > gypsum > press mud and in the Third year it was press mud > FYM > gypsum > control. The gypsum and press mud treatments produced much lower yield in the first year. This suggested that equilibrium in the soil might not have been reached quickly by gypsum and press mud treatment.

In the third year, the yield of sugarcane obtained with sulphitation press mud treatment was the best (600 g / ha) followed by FYM (567 g / ha), gypsum (510 g / ha) and control (494 g / ha). The higher yields of sugarcane obtained with organic amendment might be due to appreciable amount of plant nutrients present in such amendment (Khanna *et al*, 1956). It might be also due to the increase in the organic matter stimulating the population and activity of *Azotobacter* (Rai *et al*, 1976). Higher yields of sugar cane were also reported by applying press mud at different factory farms during 1953 - 57. The good effects of simple leaching, though of a lower degree, might be due to calcareous nature of soil and dominance of salinity. But it was apparent from the results that the improvement brought about by applying soil amendments with leaching was of higher order as compared to simple leaching. This suggested the necessity of applying soil amendment, in these usar soils. On the basis of easy availa-

bility, price and good effects on soil and yield of sugarcane, sulphitation press mud should be preferred for amelioration of calcareous saline-alkali soils.

Experiments were conducted to assess the composting value of sugarcane trash in combination with press mud and cowdung. The average analytical results of composts have been presented in Table-2. From the data it may be clear that compost prepared from cane trash + press mud (sulphitation) was the best in respect of N, P_2O_5 and K_2O contents with a relatively lower C/N ratio. But carbonation press mud was not only inferior to sulphitation press mud rather it was inferior to cow dung so far the organic carbon and nitrogen were concerned.

Composts were prepared of cane trash + press mud with various doses of phosphate with a view to know the effect of phosphate on the nutrient content of the composts.

The chemical constituents of the composts have been reported in Table-3. From the results it may be seen that addition of phosphate while composting not only increased the phosphate status of the composts but also helped in conservation of nitrogen. Addition of 10 Kg P_2O_5 per pit (3 m. x 1.5 m. x 1 m) approximately doubled the nitrogen and P_2O_5 contents of compost. But superiority of sulphitation press mud over carbonation press mud was again maintained.

Siddiqi *et al*, (1974) observed that saw dust could increase the efficiency of fertilizer applied to sugar cane. But saw dust is not easily available at all the places. On the other hand,

FYM and sulphitation press mud are available in the entire white sugar belt of Bihar. Therefore field trials were conducted in which N , P_2O_5 (chemical fertilizers) were used with without pre-mixing organic manures. The mean values of results obtained have been tabulated in Table-4.

A perusal of the data indicated relatively higher residual available P_2O_5 in soil in the treatments receiving sulphitation press mud FYM in conjunction with inorganic fertilizers. This was probably due to the higher concentration of P_2O_5 in sulphitation press mud. The data on P_2O_5 concentration in leaf sheath showed higher contents in the case of cane compost prepared with sulphitation press mud or where sulphitation press mud has been used. This indicated that the absorption of phosphate by sugarcane could also be increased by sulphitation press mud treatment.

Further the treatment receiving sulphita-

tion press mud in combination with inorganic fertilizers produced significantly highest sugarcane yield as compared to other treatments. Idnani (1966) also reported similar results with organomineral urea on wheat crop. Thus, we may say that the efficiency of nitrogenous fertilizer might have been increased by its premixing with organic manure.

The yields obtained by FYM and cane trash compost used with inorganic fertilizers were at par and significantly lower as compared to sulphitation press mud but they were superior to all other treatments. It was interesting to note that the same organic manures when applied alone could not produce any significant effect on sugar yield as compared to inorganic fertilizers applied alone. The juice quality, however, remained unaffected due to treatments. Therefore, the application of inorganic fertilizers in combination with sulphitation press mud appeared to be the best for sugarcane crop.

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Table—1
Effect of different reclamation treatments on soil characteristics & yield of sugarcane.

Soil characteristics	Initial	Control leaching alone			Gypsum			F. Y. M.			Silph Press mud.		
		1st Yr	2nd Yr	3rd Yr	1st Yr	2nd Yr	3rd Yr	1st Yr	2nd Yr	3rd Yr	1st Yr	2nd Yr	3rd Yr
pH	8.9	8.8	8.5	8.4	8.3	8.3	8.3	8.6	8.3	8.3	8.7	8.3	8.3
Electrical conductivity (mmhos/cm)	26.6	17.9	6.9	2.3	12.3	4.5	1.9	12.8	6.0	1.8	13.3	4.8	4.8
C. E. C. (me/100g)	8.65	—	—	—	—	—	—	—	—	—	—	—	—
Na-saturation (%)	35.3	24.8	12.7	11.5	8.6	6.2	5.9	14.8	11.4	9.3	18.2	7.8	6.2
Total soluble salts(%)	1.8	—	0.52	0.20	—	0.48	0.12	—	0.63	0.15	—	0.56	0.14
Yield of Sugarcane (Q/ha)	—	278	—	494	224	—	510	288	—	567	208	—	600

Table-2
Average analytical results of composts (on oven dry basis).

S.No.	Treatments	N%	P ₂ O ₅ %	K ₂ O	Org. C%	C/N.
1.	Cane trash + Cow dung	0.57	0.36	0.51	7.9	13.86
2.	Cane trash + Press mud carbonation	0.42	0.45	0.67	6.2	14.76
3.	Cane trash + Press mud (carbonation) + cow dung.	0.50	0.39	0.59	6.8	13.60
4.	Cane trash + Press mud (Sulphitation)	0.96	0.74	0.72	11.3	11.76
5.	Cane trash + Press mud (Sulphitation) + cowdung	0.70	0.59	0.76	8.9	12.71

Table-3
Average analytical results of phosphate re-inforced composts (on oven dry basis)

Sl. No.	Treatments	N%	P ₂ O ₅	Org. C%	C/N
1.	Cane trash + Press mud (Carbonation)	0.42	0.49	6.0	14.2
2.	(Cane trash + Press mud Carbonation) + 5 Kg P ₂ O ₅ (S.S.P.)	0.52	0.69	7.24	13.9
3.	Cane trash + Press mud (carbonation) + 7.5 Kg P ₂ O ₅ (SSP)	0.66	0.82	8.56	13.0
4.	Cane trash + Press mud (carbonation) + 10 Kg P ₂ O ₅ (S.S.P.)	0.72	0.98	9.01	12.5
5.	Cane trash + Press mud (Sulphitation)	0.94	0.77	11.20	11.9
6.	Cane trash + Press mud (Sulphitation) + 5 Kg P ₂ O ₅ (SSP)	1.10	0.90	12.73	11.5
7.	Cane trash + Press mud (Sulphitation) + 7.5 Kg P ₂ O ₅ (SSP)	1.54	1.38	17.40	11.3
8.	Cane trash + Press mud (Sulphitation) + 10 Kg P ₂ O ₅ (S. S. P.)	1.82	1.69	20.00	11.0

Table - 4

Effect of sulphitation Press-mud, cane trash compost and FYM on increasing the efficiency of fertilizers (Mean value)

S. No.	Treatments	Available P ₂ O ₅ (ppm)	P ₂ O ₅ % in leaf-sheath	N % in leaf	Yield of Sug. cane q/m	Juice quality	
						Pol %	Purity %
A.	60 Kg N + 70 Kg P ₂ O ₅ /ha	8.04	0.304	0.514	404	16.64	86.06
B.	A + 200 Q. FYM/ha.	9.98	0.414	0.548	493	17.23	88.26
C.	A + 200 Q. cane trash compost/ha	8.62	0.529	0.612	486	16.99	85.16
D.	A + 200 Q. Sulphitation press mud/ha	10.69	0.492	0.568	545	16.00	86.86
E.	200 Q. FYM/ha.	8.53	0.405	0.516	417	16.80	86.56
F.	200 Q. cane trash compost/ha.	8.00	0.436	0.541	406	16.49	86.10
G.	200 Q. Sulphitation press mud	9.86	0.425	0.505	428	15.89	83.68
H.	Control (No manures)	6.22	0.298	0.502	341	16.84	83.66
	S. E. Tr. (Mean)	0.13	0.006	0.018	14.4	0.48	1.48
	C. D. at 5%	0.39	0.018	—	46.4	—	—

UTILIZATION OF THE BYPRODUCTS OF SUGAR INDUSTRY PREPARATION OF XYLITOL, A NUTRITIVE SWEETENER FROM BAGASSE

By

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ABSTRACT

Powdered dry bagasse was defatted and delignified with suitable reagents. The defatted and delignified bagasse was depectinated with ammonium oxalate to furnish a sample free from fat, lignin and pectin. This sample of bagasse was extract with aqueous alkali and the alkaline extract after acidification and on treatment with rectified spirit furnished hemicellulose. Crude xylan was isolated with Fehling's solution. This copper-complex upon decomposition with furnished xylan which was hydrolyzed with acid to produce xylose. Reduction of xylose to its corresponding alcohol, xylitol, was carried out by using two reducing agents, namely, sodium borohydride and Raney Nickel. The yield of xylitol was found to be higher with Raney Nickel than with sodium borohydride reduction. The compound was characterised from its migration rate, m. p. and m. p. of its characteristic crystalline, 2, 4, : 3, 5—dimethylene derivative. Xylitol is as sweet as sucrose and has an important place in human diet as a special dietary additive.

Since the cyclamate ban there has been considerable interest in naturel sweeteners with high sweet intensities to replace ordinary sugars to reduce calories. Many diet plans have been developed and widely publicised as easy pathwyas to weight loss. Most plans are based on reduction of caloric intake or reduction in total food consumption. Fats, starches and sugars are the foods which are

always regarded as responsible for causing overweight. A foot that is low in protein and high in fats and carbohydrates is labelled "high caloric" obviously because its contribution to the diet is more calorific than nutritious.

Sugar in the form of sucrose and corn sugars has also been implicated as a causative agent in a spectrum of disorders¹ ranging from

dental caries to hyperglycemia, the aggravation of diabetes and cardiovascular diseases. In U. S. A. prior to 1970, saccharine and cyclamate were used in foods and beverages as non-nutritive sweeteners mainly as combined mixtures. With the exit of cyclamates in 1970, saccharin which is about 550 times sweeter than sucrose, became the only artificial sweetener which was officially permitted for use in foods. This, as expected, resulted in a dramatic spurt in its use. In 1977 five million pounds of this chemical were consumed in U. S. A. alone -75% of this was used in diet sodas and 25% in dietetic foods and as a tabletop sweetener in place of sugar. In India so far, part from dietetic foods, its use is permitted only in soft drinks and that too, by way of replacing one-fifth of the sucrose required for the drink. Not only foods and beverages, but cosmetics such as lipsticks mouthwashers and toothpastes as well as various drugs are currently using small amounts of saccharin to improve flavour. As far diabetic patients, saccharin has been their mainstay for years together. Needless to say, as of now, life would be an ordeal for all diabetics without this sweetener. Whether saccharin is as safe as it is sweet, is, however, another question. During the last few years possible health hazards of this sweetener have created quite a controversy among scientists and drug control agencies. In March 1977, the federal Drug Agency of U. S. A. proposed a ban on the use of saccharin in foods, drugs and cosmetics. The above agency have accumulated evidence that the sweetener could be a potential carcinogen. National Cancer Institute of Canada also undertook research on the carcinogenic potential of saccharin and came to the conclu-

sion that among the consumers, men had a 60 per cent greater risk of contracting uadder cancer. Experiments are still in progress to establish unequivocally the carcinogenic property of saccharin.

Over the past ten years, a great deal of research has been going on to identify and develop other non-nutritive sweeteners to be used as supplements with saccharin or as replacement of saccharin. The three naturally occurring non-nutritive protein sweeteners which had received considerable attention because of their extreme sweetness are Monellin² from Serendipity berry (*Dioscoreophyllum cumminsii*), Miraculin³ from Miracle fruit (*Synsepatum dulcificum*) and Thaumation⁴ from Katemfe (*Thaumatococcus daniellii*). Monellin is reported to be 3000 times sweeter than sugar, while Miraculin is so sweet that it can even change our taste to sweet one. However these protein sweeteners are not being used much because they are not considered "safe" for human consumption. The other recently developed sweeteners are Neohesperidine⁵ and L-aspartyl-L-phenylalanine⁶ (Aspartame).

Neohesperidine, a dihydrochalcone derivative can be extracted from discarded orange or grape fruit peels and is 150-250 times sweeter than sucrose. Aspartame a synthetic dipeptide is 300-500 times sweeter than sucrose and is being used as a substitute of sucrose in many preparations. Another new group of sweeteners which is being developed in recent years is sugar alcohols produced as a result of reduction of mono and disaccharides. Examples of this class are Sorbitol, Mannitol, Xylitol, Lactitol and Maltitol. Among the sugar alcohols xylitol appears to

be a promising carbohydrate sweetener since when administered orally with adaptation, it is well tolerated and safe to the levels of 90 gm/day with no subjective or objective adverse effects. Less insulin is released into blood from xylitol than from glucose. Further, xylitol is more protective against dental caries than Sorbitol or Mannitol. The slight metabolic aberrations (e.g. soft stool) observed after proper oral xylitol dosage were transient and even not different from those seen after dosage with acceptable materials including certain common sugars. Hence xylitol has an important place in human diet as a special dietary additive⁸. Xylitol is as sweet as sucrose and has a cool taste due to higher heat of solution. Apart from its being nutritive, the importance of xylitol as a sweetener lies in the promise it holds for production of non-cariogenic confectionery products like chewing gum, sweet candy, marmalade, jams, jellies and chewable tablets.

Xylitol can be obtained by hydrogenation of xylose which can be produced from xylan containing materials. Birch wood contains a high proportion of xylan and is being used in Finland for the manufacture of Xylitol. In India, sugar cane bagasse is an important by product of the Sugar Industry. During our earlier work on the hemicellulose^{9,10} from bagasse, it was observed that bagasse hemicellulose is principally composed of a neutral polysaccharide of xylan type. The structure of the xylan was also established by methylation and periodate oxidation studies. Xylan from bagasse hemicellulose is now being used as a starting material for the preparation of xylitol and the process followed for carrying

out such a conversion has been discussed in the present communication. Preparation of xylitol from bagasse hemicellulose may be considered as a further step towards utilization of the byproducts of sugar industry.

Powdered dry bagasse was defatted by hot extraction with organic solvents. The defatted mass was delignified by treatment with a dilute aqueous solution of sodium hypochlorite followed by depectination with ammonium oxalate. Defatted and delignified bagasse was extracted with aqueous alkali and the alkaline extract after acidification was treated with large excess of rectified spirit to obtain the hemicellulosic material in the form of a dirty-white precipitate. Crude xylan was next isolated from this material as copper-complex by treatment with Fehlings's solution followed by washing with water to remove the soluble polyglucosans. The copper complex of xylan upon decomposition with acid furnished xylan which was hydrolysed with acid to produce xylose in a crystalline state. The purity of xylose was tested paper chromatographically when a spot corresponding to the pentose could only be detected.

Reduction of xylose to its corresponding alcohol, xylitol, was carried out by using two reducing agents, sodium borohydride and Raney Nickel. The yield of xylitol was found to be 60% with Raney Nickel while borohydride reduction gave a yield of 42% only. Xylitol was obtained in both cases as a white crystalline solid. Its identity was further confirmed by preparing its 2, 4 : 3, 5—dimethylene derivative by treatment with formalin solution in presence of concentrated hydrochloric acid.

The m.p.s of xylitol and its 2, 4 : 3, 5—dimethylene derivative agreed well with the values reported in the literature.

Experimental

All evaporations were carried out at 45-50°C under diminished pressure and melting points are uncorrected. Optical rotations are equilibrium values.

Chromatographic separations were carried out by the descending method on Whatman No. 1 filter papers using non-aqueous phase of 1-butanol-ethanol-water (5 : 1 : 4).

The sugars were detected with silver nitrate-sodium hydroxide¹¹ spray reagents.

Isolation of Hemicellulose

Powdered dry bagasse (120 g, 40 mesh) was extracted twice with boiling ethanol-benzene mixture (2 : 1, 2 l) to remove all fatty and waxy material. The dark brown solution was filtered off and the defatted bagasse was dried in sun for seven days. It was then shaken twice with water (4 litres each

time) at room temperature to remove all water-soluble material. Bagasse was then treated with 0.7% sodium chlorite (4 litres) for two hours at pH 4.2 (bagasse liquid ratio 1 : 40), on a boiling water-bath, when the lignin of the bagasse was solubilised. After several washings with distilled water, the residue was extracted with 0.5% and 1% solutions of ammonium oxalate solution (Bagasse liquid ratio being 1 : 25) for depectination. It was then washed several times with distilled water to make it free from oxalate ions.

The defatted, delignified and depectinated bagasse was now extracted successively with 2% sodium carbonate, 4.5% caustic potash and 10% caustic potash with constant stirring at 50°-60°C for five hours. Each extract was separately acidified with acetic acid (pH 3.8), when a very slight turbidity appeared, showing that the hemicellulose A was practically absent in the sample of bagasse. An excess of rectified spirit (3-4 volume) was then added to precipitate hemicellulose B. Each was washed with increasing concentrations of ethanol and finally with absolute ethanol when the following three fractions were obtained :

S. No.	Fractions	Yield of Hemicellulose in grams	Yield % of Hemicellulose on dry bagasse
1.	2% Sodium Carbonate extract	3.0 g	2.5 %
2.	4.5% caustic potash extract	20.8 g	17.3 %
3.	10% caustic potash extract	5.0 g	4.2 %

Isolation of Xylan from Hemicellulose

Hemicellulose (18 g; 4.5% KOH fraction) was dissolved in aqueous caustic potash (4.5%, 1.5 litres) with constant stirring and filtered. The filtrate was treated with an equal volume of Fehling's solution, when the copper-complex precipitated as a deep blue, thick, gelatinous mass. A little acetone (200 ml) was added to help in the settling down of the precipitate. The copper-xylan complex was washed thoroughly with distilled water to remove the soluble polyglucosans. The complex was suspended in distilled water (1 litre) by vigorous stirring. Cold hydrochloric acid (2 N) was then added carefully to decompose the copper-complex when a slightly opalescent solution was obtained. This when poured into large excess of ethanol (2 litre) furnished a neutral polysaccharide in the form of white flocculant precipitate. It was filtered and washed several times with absolute ethanol and dried. (Yield 8.1 g).

Hydrolysis of Xylan to Xylose

Xylan (8 g) was hydrolysed with sulphuric acid (1.5 N, 200 ml) in a boiling water bath for over 30 hours. The hydrolyzate was filtered and neutralized with barium carbonate (pH 6.5). Barium sulphate was filtered off and the filtrate was concentrated. The syrupy liquid on boiling with dry methanol afforded white crystalline solid m.p. 142° (∞) $^{22}\text{D} + 18.1$ (c 0.35 g in water) D-xylose, m.p. 144° (∞) $^{20}\text{D} + 18.6^{\circ}$ (yield 7.0 g). The compound on paper chromatography gave a single spot corresponding to an authentic sample of D-xylose.

Reduction of Xylose to Xylitol with Sodium borohydride

To an aqueous of xylose (2.5 m) in 25 ml water, sodium borohydride (2.5 g) was added in small quantities with constant stirring. After the addition was complete, the solution was stirred for ten hours more and kept overnight. Excess of sodium borohydride was destroyed with acetic acid. The solution was then deionized by passing successively through columns of freshly regenerated cation (Duolite C-25) exchange and anion (Duolite A-7) exchange resins. The deionized solution was concentrated to a syrup which was refluxed with dry methanol for eight hours. The solution was kept in ice box for a week and then at room temperature for three days, when white crystals of xylitol, m.p. $93-95^{\circ}$ (Lit¹² m.p., 92°) separated out (yield 1.05 g).

Reduction of Xylose to Xylitol with Raney Nickel at atmospheric pressure.

Xylose (2 g) was refluxed with freshly prepared Raney Nickel¹³ (25 g) in 70% ethanol (200 ml) for 5-6 hours. The catalyst was filtered and the residue washed with distilled water (20 ml). Concentration of the filtrate gave rise to a thick syrup which was crystallised in the same manner as described above to furnish crystalline xylitol m.p. $93-94^{\circ}$ (Yield 1.2 g).

Both the samples of xylitol on paper chromatography gave a single spot thus establishing its homogeneity. The identity of xylitol was further confirmed by preparing its 2, 4 : 3, 5 - dimethylene derivative according to

the procedure of Hann, Ness and Hudson¹⁴. Xylitol (0.5 ml) and 40% Formalin (0.5 ml). The reaction mixture was heated to 60°C for three to four hours. It was then cooled to room temperature and diluted with alcohol (3 ml) when 2, 4 : 3, 4 - Dimethylene - xylitol was precipitated. It was filtered and washed several times with absolute alcohol. Further purification was carried out by recrystallisation from warm water-ethanol mixture (1 : 5) when

white crystals of 2, 4 : 3, 5 - dimethylene - xylitol, m.p. 103°C (Lit¹⁴ m.p. 201—202°) were obtained.

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PRODUCTION OF HIGH FRUCTOSE CORN SYRUP BY *STREPTOMYCES* Sp.

By

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ABSTRACT

A Streptomyces strain exhibiting considerable glucose isomerase activity has been isolated from soil. The cell free extract of the culture was able to convert glucose to fructose in a period of 48 hours and gave 40% conversion of glucose. With acid hydrolysates of corn and bagasse as substrates the cell free extract gave glucose to fructose conversion of 39.8% and 29% respectively.

Introduction :

High fructose corn syrup has acquired great industrial importance in recent years. Corn syrups have been used more frequently as substitutes of partial replacements for the more expensive sucrose¹. As the sweetening power of fructose is higher than that of common sugars like sucrose and glucose, the production of high fructose corn syrups has increased tremendously in the last five years and it finds large market in the production of processed foods and drinks.

During the earlier period of development alkali treatment of glucose was more preferred for its isomerization to fructose². But, in recent years the process of the production of sweeter corn syrup became more advanced when specific microorganisms were isolated that produced enzymes capable of isomerizing glucose into fructose. These glucose isomerases made it possible to manufacture corn syrups containing sufficient fructose to make them comparable with sucrose in sweetness.³

Marshall and Kooi⁴ for the first time reported the presence of glucose in *Pseudomonas hydrophila* in 1957. Later on a number of strains have been isolated for the production of glucose isomerase e.g. *Aerobacter cloacae*⁵, *Escherichia intermedia*,⁶ *Bacillus coagulans*⁷, *Streptomyces albus*⁸, *Streptomyces phacochromogenes*⁹, *Lactobacillus brevis*¹⁰, etc. Glucose isomerase is an intracellular enzyme which is produced in large quantities only under carefully controlled conditions. Xylose acts as an inducer of glucose isomerase produced from different microorganisms. Starch and cellulose hydrolysates provide a major source of glucose for this process.

This paper deals with the enzymic conversion of glucose into fructose using an isolated strain of *Streptomyces* sp. as the source of glucose isomerase enzyme. Starch and cellulose hydrolysates were used as the source of glucose.

Methods and Materials

Organism and Culture Conditions :

A strain of *Streptomyces* was isolated from soil. The organism was maintained on RM medium¹¹ containing xylose as the main carbon source. The culture was incubated at 30° C on a rotory shaker at 100 rpm. Stock cultures were maintained on RM medium solidified with 2% agar.¹¹

For mycelial propagation and enzyme formation, 20 ml of RM medium was inoculated with mycelium from a three day old slant and then the total content was transferred to a 250

ml. Erlenmeyer flask containing 100 ml of RM medium and incubated under above mentioned conditions for 40 hours.

Preparation of Enzyme :

The mycelium pellets were collected by filtration through What man No. 1 paper and washed with water. The enzyme was extracted by disrupting the cells for 15 mins at 25 Kc in an (Ultrasonic Processor Model P-2 of Vibronics Ltd). The cell debris were removed by centrifugation at the clear supernatant was used as the crude enzyme preparation.

Assay of Enzyme :

Enzyme was assayed according to the method of Takasaki *et al*³ and the product was estimated by cysteine carbazole method². One unit of glucose isomerase was defined as the enzyme amount that produced one mg of fructose from glucose under the above assay conditions. Protein was determined by Lowry's method¹² using bovine serum albumin as standard. The assay mixture contained 60 µg of protein per ml.

Corn Hydrolysate :

5 gm corn was suspended in 50 ml water. Then the sufficient amount of concentrated hydrochloric acid was added to obtain 1 N concentration and the suspension was autoclaved at 150° C for 30 minutes. The remaining corn material was removed by filtration. The pH of filtrate was adjusted to neutral and it was concentrated under reduced pressure to remove excess of HCl. The reducing sugar

content in the concentrated hydrolysate was determined by DNS method ¹⁴.

Bagasse Hydrolysate :

Powdered bagasse (65 mesh) was first treated with 5% sodium hydroxide for 10 minutes at 30–35° C, thoroughly washed to remove the excess alkali and was hydrolyzed by autoclaving with 2.5% sulphuric acid at 150° C for 30 minutes. After hydrolysis the residue was separated by filtration, and pH of filtrate was adjusted to between 6–7 with addition of calcium carbonate. The contents were filtered off and precipitate of calcium sulphate was washed with distilled water. The filtrate along with washings was concentrated under reduced pressure and the reducing sugar concentration was measured by DNS method and adjusted to the desired level.

Conversion of Glucose into & Fructose :

The conversion was carried out by mixing 0.2 M potassium phosphate buffer (pH 7.2), 0.01 M $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$, 2 M glucose and 360 μg enzyme protein in a total reaction mixture volume of 6 ml. This mixture was incubated at 70° C for 3 days. At regular intervals the contents were analysed for fructose using cysteine carbazole method. In the case of hydrolysates, glucose was replaced by corn and bagasse hydrolysates (keeping the same molar concentration of glucose) and reaction was carried out as above.

Polarimetric determination of Fructose :

The formation of fructose was confirmed polarimetrically by measuring the optical

rotation of reaction mixture at regular intervals of time. Using a 100 mm polarimeter tube.

Chromatographic Examination :

The reaction product was identified by chromatographic analysis using paper chromatographic techniques with Butanol : Pyridine : Water (6 : 4 : 3) and Butanol : Acetic acid : Water (4 : 1 : 5) solvents.

Results and Discussions :

Conversion of glucose into fructose by glucose isomerase enzyme was carried out under optimum conditions of reaction. It was found in preliminary studies that this *Streptomyces* glucose isomerase gave maximum conversion at pH 7.2 temp. 90° C, substrate concentration of 2 M glucose, 0.01 M $\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}$ and 60 μg enzyme protein per ml. For the ease of handling, the reaction was carried out at 70° C.

Table I shows the optical rotation of reaction mixture at different time intervals. The change in the value of optical rotation from positive to negative side is a clear indication of formation of laevorotatory product from dextrorotatory substrate glucose. This polarimetric data confirms the formation of fructose from glucose.

It can be seen from Fig.1 that with glucose as substrate, the maximum conversion to fructose of 40% is obtained in 48 hours of time. But in the case of corn and bagasse hydrolysates the reaction takes 72 hours and 58 hours time with maximum conversion of 39.8% and 29% respectively.

Both corn and bagasse produce reducing sugars on treatment with acid. Corn being known to be rich in starch content, its hydrolysis results in higher proportion of glucose. Bagasse is a complex consisting of cellulose, pentosan and lignin. Treatment of bagasse with 5% sodium hydroxide for 10 minutes results in solubilization of part of pentosans and lignin and makes the cellulose part more easily hydrolysable. However, the hydrolysate contained considerable amount of pentoses as shown by test with the orcinol reagent. The xylose present in the reaction mixture competes as an alternative substrate. This may be the reason for the decreased conversion rates in the case of bagasse hydrolysate. Also there are reports of xylose being converted to xylulose by the enzyme. Corn hydrolysate works as good as pure glucose but it takes longer time for the same amount of conversion (Fig. 1).

The *Streptomyces sp.* used here, essentially required xylose as carbon source for producing glucase isomerase. The cost of this process can be reduced on an industrial scale by replacing the expensive xylose by xylan containing materials such as wheat bran, corn cobs, rice husk, wheat straw, bagasse etc. The hydrolysis of corn and bagasse may also be carried out by enzymic procedures using glu-

coamylase extracted from *Aspergillus niger* and cellulase enzyme of *Trichoderma viridie* respectively

High fructose corn syrups contain 45% fructose and 55% glucose and have been used as sweetening agents in place of sucrose³. Enzymatic conversion of glucose to fructose has also been achieved by using heat treated microbial cells⁸⁻¹⁵ or by -immobilized enzyme systems¹⁶. In the present studies we have been able to achieve 40% conversion with cell free extract of *Streptomyces sp.* This strain is found to have heat tolerance and is therefore potentially capable of yielding high conversion with heat treated cells or immobilized enzyme systems. Further work is in progress with such systems.

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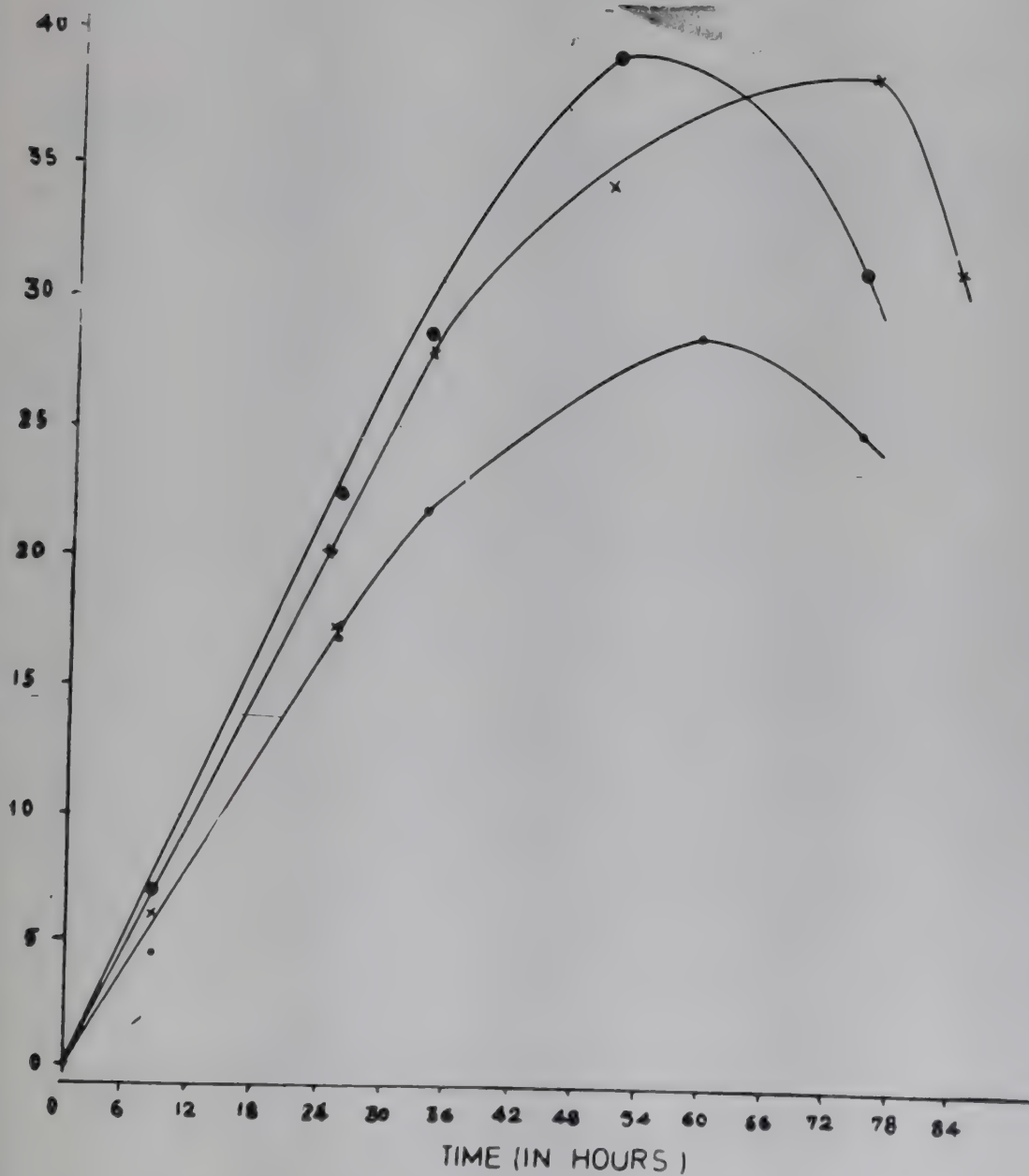
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Table - 1**Decrease in Optical rotation on formation of fructose from glucose.**

Time Interval (in hours)	:	Optical rotation (in degrees)
0		3.14
8		3.00
34		2.82
32		2.75
48		2.45
56		2.40

% CONVERSION

- GLUCOSE - FRUCTOSE
- x—x CORN HYDROLYSATE - FRUCTOSE
- BAGASSE HYDROLYSATE - FRUCTOSE



CONVERSION OF GLUCOSE INTO FRUCTOSE USING CORN AND BAGASSE HYDROLYSATE AS SUBSTRATE

PRACTICAL METHODS TO CHECK THE DOWNWARD TREND IN THE FACTORY SUGAR RECOVERY WITH PARTICULAR REFERENCE TO RAJASTHAN CONDITIONS

By

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ABSTRACT

In Northern India there exist dual problems of lower cane yields and inferior sugar recovery. The cane yields are, however, improving with the introduction of high yielding varieties and improved agro-techniques. The sugar recovery in cane is either stationary or going down in all the regions. The lower sugar recovery is adversely affecting the factory economy particularly due to absence of any system of paying the cane price on quality basis. Therefore, some practical measures are being suggested herewith so as to check the downward trend in the factory sugar recovery. The aspects of improving the sugar cane quality which are based on different factors affecting the entire cultivation and manufacturing phases are discussed in this article. The important factors which affect the maturity and cane juice quality are as follows :—

- 1. Varietal position i. e. only high sugar and good yielding cane varieties may be released for general cultivation.*
 - 2. Adoption of recommended cultivation practices particularly which are beneficial to enhance the cane quality.*
 - 3. Scientific cane supply procedures for maturity-wise supply of freshly harvested cane.*
 - 4. Physiological effects of varying climatic factors on the cane crop at different growth stages—practical manipulations thereon to reap a better quality cane crop.*
 - 5. Amending the processing and manufacturing deficiencies of the factory itself with the aim of minimising any sugar loss.*
-

Introduction :

In Northern India there exist dual problems of lower cane yields and inferior sugar recovery with the sugarcane produced for factory supply. It is an established fact that the cane yields and sugar quality in cane are having somewhat negative correlation. The cane yields per hectare are regularly increasing due to introduction of new promising varieties and adoption of improved cultivation practices, but it has been found that there is no increase in the sugar recovery, and in many places it has even gone down. The cane yield affects both the economy of the cultivators and the sugar factory the former for higher returns to cultivators and the latter for adequate cane supply to the factory for full season crushing. However, the sugar quality of cane affects only the factory economy as there exists no system of paying the cane price on quality test basis as followed in many foreign countries. If the cane price is paid according to the quality basis the problem may automatically be solved. But the process of determining cane quality individually is quite complicated and tedious, particularly due to absence of any sophisticated mechanism in the Indian sugar factories. Therefore, in the present circumstances, we may follow some other simple and practical methods systematically so that the downward trend in the sugar recovery is checked. Some of those methods are discussed as follows.

(A) Varietal position

The varieties having high yield potential and higher sugar content and with adaptability to the prevailing agro-climatic conditions should only be released for general cultivation.

Moreover, it should be according to the required maturity phases—viz. early, mid and late maturing. It is very important for the Plant Breeders to reject outright all those newly evolved sugarcane varieties in the preliminary progeny row trial stage in which the mean hand-refractometer brix reading during early January is less than 18. After rejecting the low sugar varieties the rest of the varieties may be screened for higher yield potential and categorised under three broad groups—early, mid or late maturers.

In north India the sugar factories generally start crushing from November and it extends till the month of May, which accounts for about 200 days of the crushing season. The whole season can roughly be divided into three periods, viz.—early (Nov. and Dec.), mid (Jan. and Feb.) and late (March, April and May). The early and mid periods may each require about 30% of the total cane requirement for the factory season. The remaining 40% crushing may be done during the late period from March to May. Therefore, for the early period crushing early varieties, ratoons and then autumn planted canes may be utilised and for mid period mid-early and mid-season ripeners with the remaining ratoon or autumn canes may be utilised, and for late period mid and late ripeners may be used. However, vigorous efforts in the right direction are to be made by the cane development and extension staff to make the scheme a success.

In Rajasthan the possible varietal categories for the periodical crushings are currently as follows :—

Early — Co. 449, Co. 997 and Co. 66-1

Mid—Co. 527, Co. 1007 and Co. L. 29.

Late—Co. 312, Co. 419, Co. 1111 and Co. 1253.

The category wise varietal adoption should be according to the suitability of the varieties for the different agro-climatic conditions. Further, care should be taken to avoid general cultivation of the varieties which are very prone to lodging and susceptible to diseases, pests and frost damage, as all those factors adversely effect the juice quality of cane.

(B) Adoption of recommended cultivation practices :

The Research and Extension Agencies issue time to time recommendations for scientific methods of cultivation practices and other agro-techniques on the basis of research findings. Those methods may strictly be followed for achieving higher yields of good quality canes. Some of the important recommendations are proper time of planting, adequate cane-seed rate and proper planting spacings, optimum and timely application of fertilizers, irrigations and other inputs, timely adoption of all the plant protection measures and necessary intercultural operations, propping of high growing canes and earthing up during the grand growth stage of the crop, harvesting cane as per maturity schedule, avoiding carelessness in ratooning practices etc.

(C) Scientific cane supply procedures :

The quality of the cane supplied to the factory depends much on the working efficiency of the Cane Department, even the supply is made maturity-phase-wise. The date-wise supply should be pre-planned and the cane

growers may be directed that they should harvest only that amount of cane which is indented by the factory to supply on a particular date. It has been observed, particularly, in areas where harvesting and stripping are got done free in exchange of green tops, that the cultivators get harvested and stripped excess amounts of cane and stake those in the field and wait for any fresh indent from the factory. In the process there is generally an increase in the time-lag between the actual harvesting and factory processing.

The research findings indicated that, if the weather conditions are quite mild the permissible time-lag between actual harvesting and crushing should normally be less than 4-5 days. The driage starts from the second day but the inversion of sucrose starts from the 5th day of harvesting if the canes are staked in open fields. Any adverse effect due to delay in crushing vary according to the prevailing weather conditions—particularly temperature and humidity. The cane growers should, therefore, be advised not to get harvested excess canes in advance. In long distance cane transport there is always a chance of delayed supply. Therefore, efforts should be made to develop particularly the gate zone (within 15-20 km. radius) for major cane supply to the factory and supply from far away out centres should drastically be curtailed.

Sometime due to power failure of factory break-down it becomes very difficult to do the cane management job smoothly and the problem can only be tackled if the Cane Department is very alert. When there is excess supply of cane and huge accumulation of cane in the factory yard, the canes should be pro-

perly staked—preferably under shade—and mist or fine spray of cool water may be done if the weather conditions are hot and dry.

Further, the cane growers should be prewarned that they should not supply cane bulk mixed with unclean, diseased and stale canes as otherwise those may not be accepted by the factory. Moreover, bullock cart and tractor-trolley cane supply should be preferred and truck supply should be avoided as far as possible. For out centre supplies truck transport is preferable as compared to rail wagon supply.

The cane development and supply procedures are very important for sugar factory and a team of trained and talented cane development and marketing staff should be available in each factory. Many sugar factories are neglecting this branch and therefore, they should strengthen it as early as possible.

(D) Physiological effects of varying climatic factors on the cane crop at different growth phases

The uncontrollable climate which becomes abnormal very frequently, hinders the cane's natural growth and maturity and it becomes very difficult for the cane growers to rectify any damage already done to the cane crop. However, the cane crop can slightly be got recouped and further deterioration may be checked if timely actions, particularly with some special cultural practices, are taken by the cane growers. Some of the adverse effects of the abnormal weather conditions, occurring at different stages of the crop growth thereon, are discussed hereunder.

[i] Critical Stage

Sometimes it rains in March, just after cane planting and it creates a condition of crust formation on the top of the soil which obstructs normal emergence of the sprouted cane buds. Moreover, if there is any stagnation of rain water in the field it should be drained out immediately and blind hoeing should be done as soon as tilth condition is attained. If that is not done there will be delay and inhibition of the normal shoot emergence and thereby adversely affecting the plant population and early growth vigour of the crop. Some nurseries may be maintained by the cultivators—preferably with S.T.P. system—and the gaps in the fields may immediately be filled by sprouted cane buds taken out from the nurseries.

In case of abnormally dry and hot weather conditions, which restrict the crop vigour at the early stage, more frequent irrigations with subsequent weeding and hoeings may be done. In case of application of any pre-emergence irrigation—as done particularly with dry planting methods—it should be definitely followed by blind hoeings.

[ii] Tillering stage

Early vigorous tillering is conducive to higher cane yields and earlier maturity, therefore, occasional hoeing and weeding are to be continued for dual purpose of conserving moisture in dry conditions and aerations to the underground crop growth in humid conditions—particularly in heavy soil types. Further proper prophylactic plant protection measures are to be adopted in time against early shoot borers and earlier pyrrilla incidence if the

prevailing weather conditions are favourable for the pest growth. Many seed-borne diseases which may appear at the stage due to conducive weather conditions are sufficiently got checked if hot air or hot water treated cane-seeds are used for planting. However, in absence of those facilities the cane setts may be treated with organo-mercurial compounds (aretan or agallol) just before planting.

[iii] Grand growth stage

This stage is very important from the crop growth point of view which subsequently affects the ultimate cane and sugar yields of the crop. The most congenial weather for the crop growth is humid and warm conditions. However, excessive torrential rain may create many problems to the crop, like water-logging, soil erosion, leaching away of soil nutrients and lodging of the well grown crop, which are harmful for the normal growth of the crop. Lodging is very harmful not only from cane yield point of view but also for the juice quality of cane. To safeguard the cane crop from the adverse effects of excessive rainfall one should select fields with proper facilities and do the first earthing up operation with the first monsoon rains and it should be immediately followed by propping or tying the growing canes with either trash-tie or tripod system. Both the earthing and propping operations protect the high growing canes from lodging and the former also inhibits the emergence of late tillers which seldom mature at the harvesting time and if those are supplied to the factory mixed with other mature canes the sugar recovery is adversely affected.

However, in case of failure of monsoon or

scanty rains if timely irrigations are not applied the crop growth will greatly be hampered. Moreover, the canes in drought conditions not only give poor yields due to poor growth and hollow-pithy conditions of the canes but will also be poor in sugar recovery point of view due to more fibre development and less juice content.

[iv] Maturity stage

At this stage if the weather conditions become abnormal there is no significant effect on the crop yield as the vegetative growth nearly stops by that time. But the weather conditions create an enormous impact on the sugar quality cane. If the humid and warm conditions with occasional rains or cloudiness extended beyond September it produces very deleterious effects on the sugar cane, quality as those conditions favour the extension of the vegetative growth of the cane crop. The weather conditions should be dry and cool (particularly higher diurnal temperature variations) with bright sunny days for higher sugar accumulation in cane. Therefore, humid and warm conditions, if extended during the maturity phase delay cane maturity and reduce sugar accumulation process in canes. That process is got aggravated if the last dose of nitrogen fertiliser is applied beyond mid July. It is rather beyond human control to alter the natural weather conditions but a little useful effects on the cane maturity may be created by adopting some precautionary measures like no application of any dose of nitrogen beyond June and keeping the vegetative growth factors, as far as possible, subdued by artificial means. For that any irrigations during the maturity phase may be

delayed and some growth retardants like Cycocel, Planofix, Cycloleucine, Polaris, Sodium metasilicate, Maleic hydrazide etc. may be used. However, with all the above efforts only a small part of the weather damage is recuperated, hence it is more practical if the factory crushing is delayed a bit if the prevailing climatic conditions during November continues to be favourable for extension of the vegetative growth of the cane crop.

It is a known fact that the maturity of the cane crop majorly depends on the prevailing agro-climatic conditions (particularly the climate) although the other factors like genetic characters and age of the crop also have some effects on the crop maturity. The climatic factor cannot be manipulated much but the cane growers may adopt easily the other special practices which may advantageously affect the other concerning factors, like agro-techniques, genetic characters and age of the crop etc. The agro-techniques have already been discussed above. As regards genetic characters, the cane growers should cultivate only those varieties which are good in cane yields, having high sugar content particularly at early or mid season periods, tolerant to pests and diseases and not prone to lodging and frost damage. If the prevailing variety gets deteriorated, efforts should be made to replace the same with a new promising variety as possible.

As regards the factor of crop age, it can easily be manipulated by time of planting and ratooning. It was found that autumn planted cane and good ratoon crops mature a bit earlier due to their earlier start of the plant life cycle. Therefore, the factory reserved

area should contain at least 1/3rd of the total area under ratoon and autumn planted cane crops. Those may be available in addition to the early maturing varieties for early crushing from November to mid January.

(E) *Processing and manufacturing deficiencies of the factory itself*

If the machineries of the sugar factory are quite old and the technical staff of the different sections are not very careful, there are always chances of inefficiencies and significant losses in the sugar recovery processes. Those losses may be either physical or chemical.

The physical losses may occur throughout the processing procedures—cane weighment to bagging of sugar. To minimise those losses there should be installed automatic and self recording cane and juice weighing systems, thorough and efficient juice extraction to minimise the loss of juice or sugar in the bagasse, reducing losses of sugar in press-mud and molasses and stopping the leakage losses if any during the entire manufacturing processes. If the technicians of the different sections are vigilant all those losses may be minimised and higher sugar recoveries are obtained.

The chemical losses may occur from the juice extraction stage to the boiling processes. There are possibilities of increased loss of sugar with the aggravation of fungal and bacterial activities in the juice due to the crushing of unhealthy and bad quality canes, contaminations from other sources and prevalence of favourable temperature, humidity and pH conditions. The remedy lies with the timely use of proper quantities of

remedial detergents to inhibit the fungal or bacterial activities.

Summary and conclusions

The price of the raw material cane constitutes more than 60% of the manufacturing cost of sugar. Therefore, any slight variation in the cane price will quite significantly effect the factory economy, particularly when the payments for cane are not made on the quality

test basis. However, the price of cane not remain stationary due to ever increasing cost of cultivation and competition with other crops. Therefore, the only alternative left to improve the situation is to enhance the quality of the cane produced for the factory supply. Further, all possible manufacturing losses should be minimised at the factory level, so that any advantage accrued by improving the quality of the raw material cane may not be nullified.

DIALYSIS OF CARMELS : ULTRAVIOLET SPECTROPHOTOMETRIC AND CHROMATOGRAPHIC BEHAVIOR OF COMPONENTS CONSTITUTING CARMEL

By

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ABSTRACT

Caramels prepared by heating of sugars in soiled state gives a well defined peak at 282 nm., while that prepared by the reaction of glucose with caustic alkali at 270 nm. in ultraviolet region of the spectrum. These caramels were dialysed to show that the peaks as above could be fractionated into a number of well defined peaks from 240 to 290 nm. when these were dialysed under stirring or unstirring conditions. The caramel remaining inside the dialysis bag during different period showed well defined peaks. UV peaks at different positions were exhibited in the solution dialysing out. Chromatographic studies showed that the low molecular weight compounds (high Rf value) present initially in the caramel could also be fractionated by the dialysis experiment. Low molecular weight compounds dialysed out in preference to the high molecular weight compounds. As the dialyses proceeded, the high Rf value compounds could be completely eliminated in the initial stages, which was followed by the compounds of the intermediate Rf values. The compounds having zero Rf value was also found in the intermediate intervals. This was attributed to its being consisting of groups of colorants having zero Rf value.

Introduction

Sugars are generally sweet and colourless. As they are heated in dry state above their melting points, they melt, turn pale yellow, amber, or orange brown reddish and finally to dark or black residues. This is accompanied

by change of taste from sweet to burnt, bitter and acrid flavours and emission of fragrant ethereal acceptable or otherwise notes. Colour development also takes place in solution when reducing sugars are heated along with alkalies—mild or strong, at elevated temperatures. In both the cases, the colouring matter formed

is termed as caramel, which has been the subject of study by a large number of workers including the authors. Onda and Urakabe made¹ ultraviolet studies on caramels and showed variation in its characteristic behavior. It was found that the position of maximum absorption changed when the sugar solutions were heated for increasing intervals of time from 265 to 285 nm and was also dependent on pH. Agarwal and Misra² showed an interesting contrast in the absorption behavior of caramels prepared by different procedures. The caramel prepared by heating sugars in solid state alone showed one characteristic absorption peak at 282 nm, while that prepared by heating the reducing sugars in presence of alkalis in solution phase at 270 nm at all concentrations irrespective of the nature of the reactants. Strict obedience of Beer's law was found at 282 and 270 nm for the two types of caramels in the ultraviolet region in the concentration ranges amenable for studies. This difference was attributed to the difference in the functional groups and structural environment. Sapronov³ has reported absorption peaks for caramel at 225 and 282 nm. The chromatographic studies of the authors^{4,5} showed the variation in the constituents composing caramels first by employing the well established solvent consisting of *n*-butanol; ethanol : Water : 4 : 1 : 5 and later a modified solvent *n*-butanol : ethanol : water : 2 : 2 : 1. The new solvent was found superior by the authors⁶ in resolution of caramel into more spots. It was found that 4 high and 5 low molecular weight compounds were produced during caramilisation by heating of sugars in solid state, while the number of such compounds produced in solution phase depended on the concentration

of both the reducing sugars and the alkalis employed. At low concentrations of the reactants, 4 high molecular weight compounds could be detected, whose number increased with concentrations to 6 or 7 and even to 8 in addition to 3 low molecular weight substances. Agarwal and Gupta⁷ attempted fractionation of caramel constituents under low voltage (200-500 V), two dimensional electrophoresis in boroax buffer and organic solvent-buffer system which could yield fractions of caramel, whose number and pattern differed with the nature of the caramel, yet the separation was not so well marked as with paper chromatographic technique. Binkley^{8,9} has identified a number of tri- and tetra-saccharides as isolated from colorant from molasses having keto groups. 1-kestose and 6-kestose were also isolated.

Attempts to isolate the main colorant from molasses by dialysis were made by Binkley,¹⁰ who found its empirical formula as $C_7H_{26-27}O_{10}N$, with a molecular weight of 27000 ± 1000 , while Underwood and coworkers¹¹ separated it by ionexchange chromatographic technique to show its empirical formula as $C_8H_{27}O_{12}N$. It is, however, significant that these contained nitrogen as well. Some of the constituents were thus isolated and studied. The present work deals with the spectrophotometric and chromatographic behaviour of the caramel fractions during their fractionation, when caramels themselves form a single well defined peak in the ultraviolet region of the spectrum at certain fixed position as a composite peak.

Experimental :

Caramel were prepared either by heating sucrose in solid state or from glucose and

alkali in solution phase under thermostatic conditions. 25 g. of sucrose was heated in the test tube placed in an oil bath for about 25 min at $210 \pm 5^\circ \text{C}$, till it acquired a dark brown colouration after initial dehydration. This was dissolved at fixed concentration for the studies. Glucose was heated with sodium hydroxide at $70 \pm 0.1^\circ \text{C}$. The equilibrium concentration of glucose was 0.275 M and alkali 0.25 M. The heating was done for about 60 minutes in each case before quenching the reaction and subjecting caramels to dialysis. The dialysis was done in a cellulosic tubular membrane 2.5% dia, 0.0023" wall thickness (Cat. No. 70160 C, Central Scientific Co., Chicago, Illinois, U. S. A.) having a length of about 10". This was filled with the desired caramel solution and saturated with toluene, and placed in a percolator containing distilled water, also saturated with toluene. The general practice/during dialysis is to keep a continuous flow of fresh toluene saturated distilled water in the outside vessel at a fixed speed. This practice was not followed in the present studies. 1000 ml of caramel solution was placed inside the dialysis bag and the water level in the outside vessel was kept equal to the inside level for intervals as specified in the tables or the figures. The aqueous solution was completely replaced thereafter for a period corresponding to every observation. The dialysis was carried out under two conditions (a) when the inside caramel solution was stirred continuously at a rate of about 10 r. p. m.; (b) When the inside solution was left undisturbed. The inside and outside solutions at the specified intervals were examined spectrophotometrically and chromatographically. Colour measurements were made in 1 cm Silica Cell on a Beckman DU Spectrophotometer

and the chromatographic resolutions was made by the solvent mixture consisting of ethanol : butanol water :: 2:2:1 and the identification of the spots made by spraying alkaline silver nitrate.

Results and Discussions

Fig. 1 gives the nature of the UV spectra obtained when caramel solution as prepared by heating of sugar in solid state was dialysed. Fig. 1a gives the nature of the curve obtained on examination of the caramel solution before dialysis. The solution was suitably diluted before recording its behaviour. It gave a well defined peak at 282 nm in accordance with the earlier observations. Fig. 1 gives the UV-behaviour of the constituents from caramel remaining inside during dialysis at different time intervals. Within 2 hours of the dialysis peaks at 271, 278, 280, 282, 284 and 286 nm. could be observed. After another two hours (4 hours interval), it was found that quite a few components were completely dialysed out, and only feeble peaks at 263, 271, 273 and 284 were seen, which included two new peaks at 263 and 273. The only dominant peak was at 282 nm, which corresponded to the original peak. The weak peaks were eliminated on further dialysis after 10 hours of the start of the dialysis leaving some old and some new ones at 243, 259, 262, 271 and 284, which further confirmed the selective elution of substances with progressive dialysis. After a period of 24 hours and more, the only peak exhibited by the inside solution corresponded to 282 nm. indicating that all other constituents were eluted out during dialysis but for the main colorant.

Fig. 2 b showed that the caramel dialysing

out the dialysis bag was fractionated and new peaks were observed. These were at 272, 274, 281 and 283 nm, which was the result of elution from inside the dialysis bag of low molecular weight compounds, which changed the equilibrium of the constituents of caramel. Further dialysis for 4 hours resulted in a broad peak covering both the peaks at 272 and 274 nm into a single one. The intensity of the peak at 283 (284) nm. increased beyond that of 282 nm. Within 10 hours, new peaks appeared at 258, 263 and 269 as may be seen from Fig. 2d, while the peaks in the region 281 to 284 again merged into a single peak at 282 nm corresponding to the original peak of caramel. Within 48 hours, the peak at 272 acquired prominence, while the peak at 263 was retained. The only prominent peak was, however, at 282 nm. After 96 hours of dialysis all side peaks were eliminated and the only peak left was at 282 nm, which was for the original caramel as well. Outside caramel was thus resolved into a number of peaks, that are being reported for the first time.

Fig. 3 showed the results obtainable during dialysis, when the caramel solution was not stirred and the dialysis was carried on under undisturbed conditions. Minor movement of the bag was caused during the change of solvent from the outside vessel during emptying out and filling with water. The colour elution under these circumstances was quite slow. Though observation were made after every 2 hours on the UV spectra of the solutions as they acquired more and more coloration, no observation worth reporting was noted. The change in the nature of the spectrum was observed only after a lapse of 24 hours of the start of the dialysis, when quite a good number

of peaks could be observed in caramel. New peaks were seen at 242, 268, 273, 276, 280 and 285 nm in addition to the usual peak of 282 nm. The rate of diffusion of the colouring matter during this period was less than that was observed, when stirring was done inside the dialysis bag even for 2 hours as observed from the colour intensity. Another day of dialysis gave two weak peak at 241 and 259 and 4 prominent peaks at 271, 278, 282 and 289, showing incomplete elimination of a few components and dominance of a few others. The number of peaks given on dialysis after 72 hours was more than that observed earlier and fractionation into peaks at 245, 258, 264, 268, 275, 282, 285 and 290 nm, which covered most of the peaks observed after dialysis of the first two days, was observed. Elimination of peaks commenced only after 96 hours of the dialysis and only 5 peaks were left at 245, 272, 279, 284 and 290. Further dialysis for a day i.e. after 120 hours, yielded the peak corresponding to the original peak of 282 nm and complete elimination of all others.

Fig. 4 gives the break down of the colorant into fractions preferable dialysing out at different intervals. Peaks were observed at 272, 278, 282, 287 and 290 nm. after 24 hours. Another day of dialysis yielded only a few sharp peaks at 275, 278, 282 and 287 indicating the preferential elution of some of the components. The figure obtainable after 72 hours of dialysis showed fractionation into peaks at 245, 258, 264, 268, 275, 282, 285 and 290, which covered most of the peaks observed on the first two days. Only after 96 hours of dialysis, more peaks were eliminated and their number reduced to 5 including those of 245, 272, 279, 284 and 290. Beyond this period,

the dialysis did not yield any sharp peak and only one diffused peak near 282 nm. could be observed.

observed during the course of dialysis, when carried out with and without stirring as remaining inside the dialysis bag and dialysing out.

Tables 1 and 2 gives the important peaks

Table-1

Caramel prepared by direct heating of sucrose, Dialysis under stirring conditions

Time in hrs.	Peak Values (nm.)	
	Caramel remaining inside the bag	Caramel coming outside the bag
0	282	
2	271, 278, 280, 282, 284, 286	272, 274, 281, 283
4	263, 271, 273, 282, 284	272, 274, 281, 283
10	243, 259, 262, 271, 284	258, 263, 269, 282
48	282	263, 272, 282
96	282	282

Table-2

Caramel prepared by heating of sucrose. Dialysis under unstirred condition

Time in hours	Peak Values (nm)	
	Caramel remaining inside the bag	Caramel coming outside the bag
0	282	
24	242, 268, 274, 276, 280, 282, 285	272, 278, 282, 287, 290
48	241, 259, 271, 278, 282, 289	275, 278, 282, 287
72	245, 258, 264, 268, 275, 282, 285, 290	282
96	245, 272, 279, 284, 290	282
120	282	282

It is possible that quite a few components may have the same or close wavelength of maximum absorption¹².

Tables 3 and 4 gives the chromatographic studies on the caramel during dialysis, when the solution was kept unstirred in the bag.

Initial caramel showed all the spots as given by such caramel in earlier studies and had Rf values of 0, 0.04, 0.08, 0.12, 0.17, 0.22, 0.26, 0.38, 0.47 and 0.63. Table 3 gives the spots that could be located in the caramel inside the bag after different intervals.

Table-3

Caramel prepared by heating of sucrose. Dialysis under unstirred condition caramel remaining inside the dialysis bag.

Time of dialysis in hrs.	No. of spots	Rf. values of spots w. r. t. Glucose
0	10	0.0, 0.04, 0.08, 0.12, 0.17, 0.22, 0.26, 0.38, 0.47, 0.63
24	7	0.0, 0.04, 0.08, 0.12, 0.17, 0.22, 0.26
48	6	0.0, 0.04, 0.08, 0.12, 0.17, 0.22
72	3	0.0, 0.04, 0.08
96	1	0.0

It was found that the fast flowing low molecular weight compound having Rf values of 0.38, 0.47, and 0.63 were completely dialysed out within 24 hours. Another day of dialysis yield six spots upto that having Rf value of 0.22 (glucose). 72 hours of dialysis resulted in only 3 low Rf spots on chromatographic analysis having Rf values of 0.0, 0.04 and 0.08. The only spot that could be located

thereafter corresponded to $Rf=0$, that is to the main colorant.

It was found that all the compounds could be spotted out in the solution dialysing out of the bag in 24 hours time interval. The only compound that could be identified after 48 hours of dialysis had.

Table 4

**Caramel prepared by heating of sucrose. Dialysis under unstated condition.
Caramel dialysing out of the dialysis bag.**

Time of dialysis in hrs.	No. Spots	Rf. values of spots w. r. t. Glucose
0	0	—
24	9	0.04, 0.08, 0.12, 0.17, 0.22, 0.26, 0.38, 0.47, 0.63
48	5	0.04, 0.08, 0.12, 0.17, 0.22
72	1	0.0
96	1	0.0

Rf values of 0 and 0.4, indicating complete elution of higher Rf value compounds in this period. It is also possible that the concentration of these compounds may have fallen low enough to be detectable chromatographically. Thereafter only spot having zero Rf value could be located.

The above observations showed that the spectrophotometric peaks could be seen at comparatively lower concentration than that was possible by the chromatographic technique, which did not yield the corresponding spots. Another important aspect may be that a large number of similar components may have the same Rf values, as for example the Rf value of fructose and mannose are the same and, therefore yield only one spot corresponding to two components. It is also possible that many similar substances may yield the peak at a particular wavelength and a single peak may be indicative of quite a few compo-

nents. An isolated functional group not in conjugation with any other group, known as chromophore, exhibit absorption of a characteristic nature in the ultraviolet or visible region. If a series of compounds have the same functional group (S) and no complicating factors, all such compounds will generally absorb at very nearly the same wavelength. Some of the known functional groups absorbing in the concerned ultraviolet region, are carbonyl groups of aldehydes and ketones absorbing in the region 295 nm and organic acids near 250 nm. Unsaturation, steric effects, conjugation and presence of auxochromes cause shift in the absorption maxima. The closeness of the absorption peaks observed during the above studies indicated that the increasing molecular weights of the compounds in the caramel as a result of condensation and polymerisation during the caramelisation of simple sugars.

Essentially similar results were obtained on dialysis of caramel prepared by heating glucose and alkali in the solution phase. Such caramels exhibit peak at 270 nm and the number of compounds detectable in the caramel in earlier studies was found to vary with the experimental conditions. The ultraviolet peaks observed during dialysis when the caramel inside the dialysis bag was stirred were given in Table 5. It may be seen that the Caramel, taken initially had only one characteristic peak at 270 nm, which fractionated to peaks whose wavelength of maximum absorption varied from 238 to 284 and 4 to 5 peaks

were observed at different intervals of times of dialysis. The only peak left after completion of dialysis showed only a diffused broad at 270 nm, which corresponded to the main colouring matter. A similar observation was given for the caramel components dialysing out of the cellulosic tubular membrane. It was quite interesting that the peaks remaining exhibiting in the inside and outside solution were in different positions in the beginning stage. Thus at 2 hours time interval, the inside peaks were at 255, 260, 264, 270 and 283, while the peaks in the outside solution were at 240, 258, 263, 266, 275 and 292 nm.

Table-5

**Caramel prepared by Glucose and Alkali Equilm. Concentration of Glucose-0.275 M.
Equilm Concentration of NaOH - 0.25 M Dialysis under stirring condition.**

Time in hrs.	Peak values (nm)	
	Caramels remaining inside the bag.	Caramel coming outside the bag.
0	270	
2	255, 260, 264, 270, 282	240, 258, 263, 266, 275, 292
4	260, 266, 274, 284	243, 255, 270, 273
6	243, 266, 270, 280	253, 263, 270, 280
8	240, 262, 270, 280	265, 270, 275
10	238, 267, 282	252, 265, 285
24	240, 274, 280	265, 278
72	240, 265	270
96	270	270

Common peaks appeared from 6 hours time intervals, when peaks at 270 and 280 were common while those at 243 and 266 in the inside solution and 253 and 263 nm. in the outside solution were different. On completion of dialysis, the outside solution showed

peak of diffused nature only at 270 nm.

Essentially similar results were given when the caramel solution in the dialysis bag was left unstirred as may be seen from Table 6.

Table-6

Caramel prepared by Glucose and Alkali. Equilm. Concentration of Glucose-0.275 M Equilm. Concentration of NaOH — 0.25 M. Dialysis under unstirred condition.

Time in hrs.	Peak values (nm.)	
	Caramel remaining inside the bag.	Caramel coming outside the bag.
0	270	
24	238, 241, 248, 255, 265, 270 278, 282, 284.	244, 248, 250, 260, 266, 279
48	236, 249, 252, 259, 262, 265 269, 272, 284	254, 259, 264, 266, 271
72	250, 266, 284	240, 251, 262, 270, 279
96	270	270

Dialysis for 8 hours period did not yield any new peak in the inside or outside solution. By next day, however, the solutions showed more peaks in the solutions. Inside caramel showed peaks at 238, 241, 248, 255, 265, 270, 278, 282 and 284, nm, while the outside solution showed a few common or different peaks as well at 244, 248, 250, 260, 266 and 279, i.e. three peaks were common. A similar situation was exhibited on other days.

A common feature of dialysis of the two types of caramel was exhibition of peak at 282 and 270 nm in the outside solution right after same time, which showed that the main colorant exhibiting the peak at their respective position may themselves be consisting of polymers or condensation products of different molecular weights but of zero Rf. value only.

The caramel prepared by alkaline reaction of glucose at elevated temperature showed more

components by chromatographic analysis. The caramel taken in these studies had 7 low Rf. value and 3 high Rf value components (with respect to glucose having Rf value of 0.22). Such a caramel was examined when the dialysis was done under unstirred conditions. The inside solution (see Table 7), showed compounds of Rf values 0.04, 0.055, 0.07, 0.11, 0.14, 0.17, 0.17, 0.22, 0.26 and 0.31, but within 24 hours, only the low Rf value spots

were left and the rest dialysed out. Another day of dialysis eliminated one more component ($R_f=0.17$) from the Caramel, while two days of dialysis resulted in retention of only three low Rf value components of Rf. 0.04 and 0.053. At the 72 hours of dialysis, the only detectable component in the bag had $R_f=0$, which corresponded with the main colorant, which was the only component left on continuing the dialysis.

Table-7

Caramel prepared by Glucose and Alkali, Equilm. Concentration of Glucose — 0.275 M, Equilm. Concentration of NaOH — 0.25 M Dialysis under unstirred condition caramel remaining inside the dialysis bag.

Time of dialysis in hrs.	No. of Spots	Rf. values of spots w. r. t. Glucose
0	10	0.0, 0.04, 0.05, 0.07, 0.11, 0.14, 0.17, 0.22, 0.26, 0.31.
24	6	0.0, 0.04, 0.05, 0.07, 0.11, 0.14
48	3	0.0, 0.04, 0.05
72	1	0.0
96	1	0.0

The spots dialysing out with time (see table 8) also confirmed the above findings.

The first day of the dialysis resulted in preferential elution of high Rf value components, four of which having Rf values of 0.17, 0.22, 0.26 and 0.31 could be seen upto 42

hours of dialysis, whereafter, these were not detectable. This was followed by complete elution of components having Rf values of 0.07, 0.11 and 0.14, which were not detected after 72 hours of dialysis. The sequence continued and after 96 hours time interval, only zero Rf value component could be seen

Table-8

**Caramel prepared by Glucose and Alkali, Equilm Concentration of Glucose—0.275 M
Equilm Concentration of NaOH — 0.25 M., Dialysis under unstirred
condition caramel coming outside the dialysis bag.**

Time of dialysis in hrs.	No. of spots	Rf. Values of the spots w. r. t. Glucose
0	0	—
24	8	0.05, 0.07, 0.11, 0.14, 0.17, 0.22, 0.26, 0.31
48	5	0.04, 0.05, 0.07, 0.11, 0.14
72	2	0.04, 0.05
96	1	0.0

dialysing out. Dialysis is without stirring only showed down the process of elimination of high Rf (low mol. wt.) components.

It was thus established, that the Caramels could be fractionated and detected into more component spectrophotometrically than that was possible in the earlier studies by chromatographic technique. A correlation in Rf. and

peaks values was however, not achievable in the present investigations.

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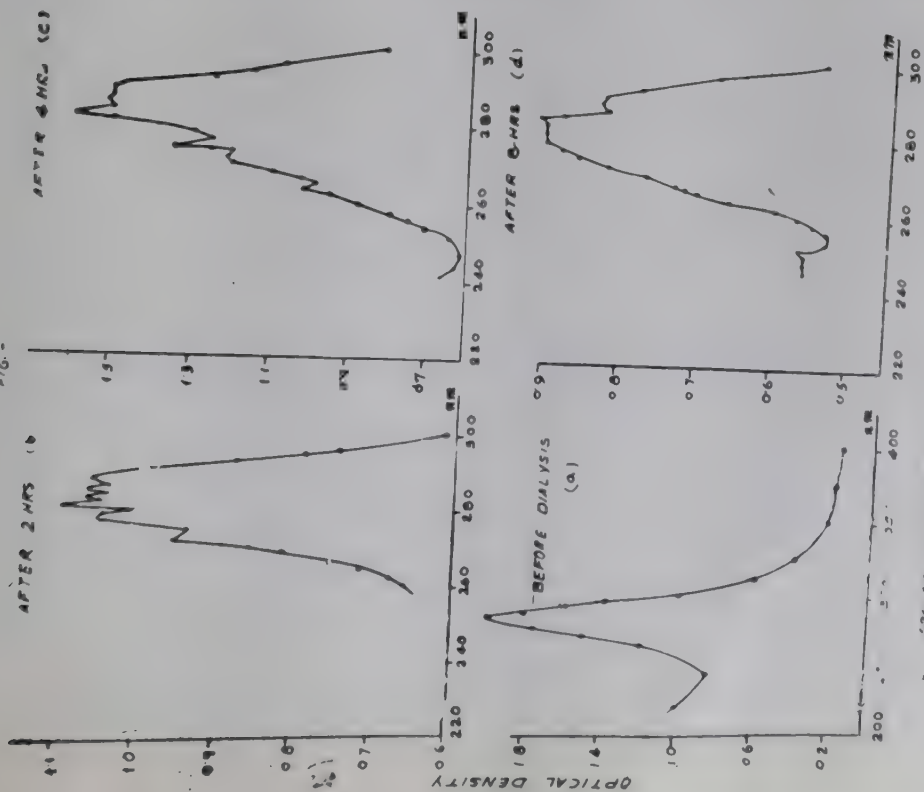
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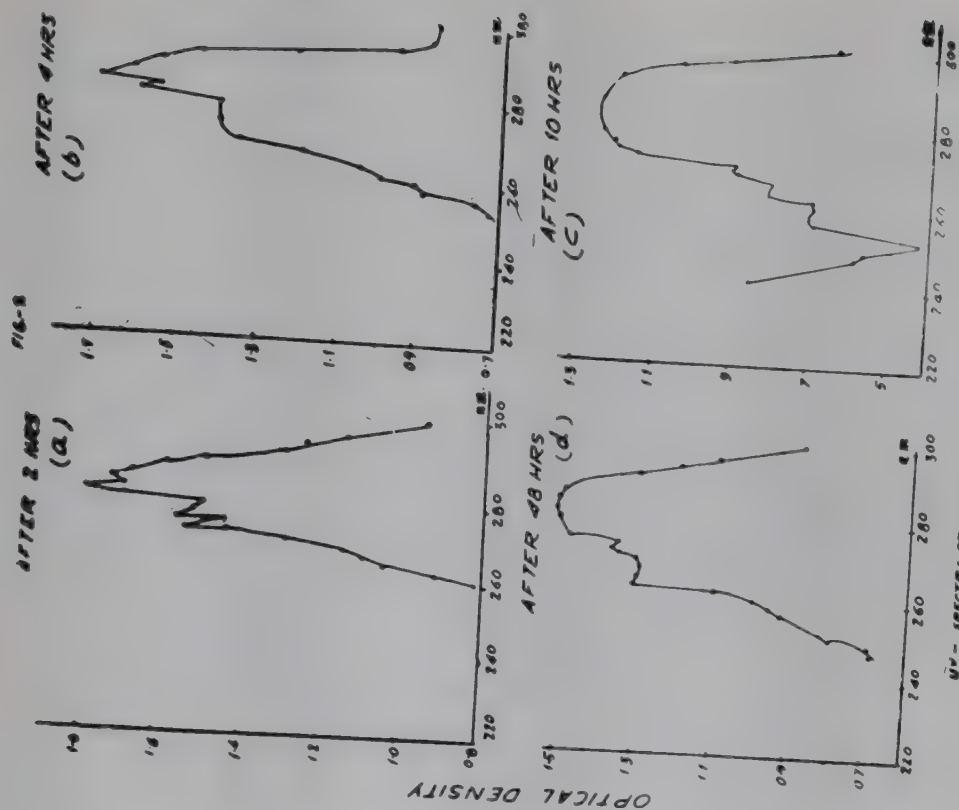
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FIG. -

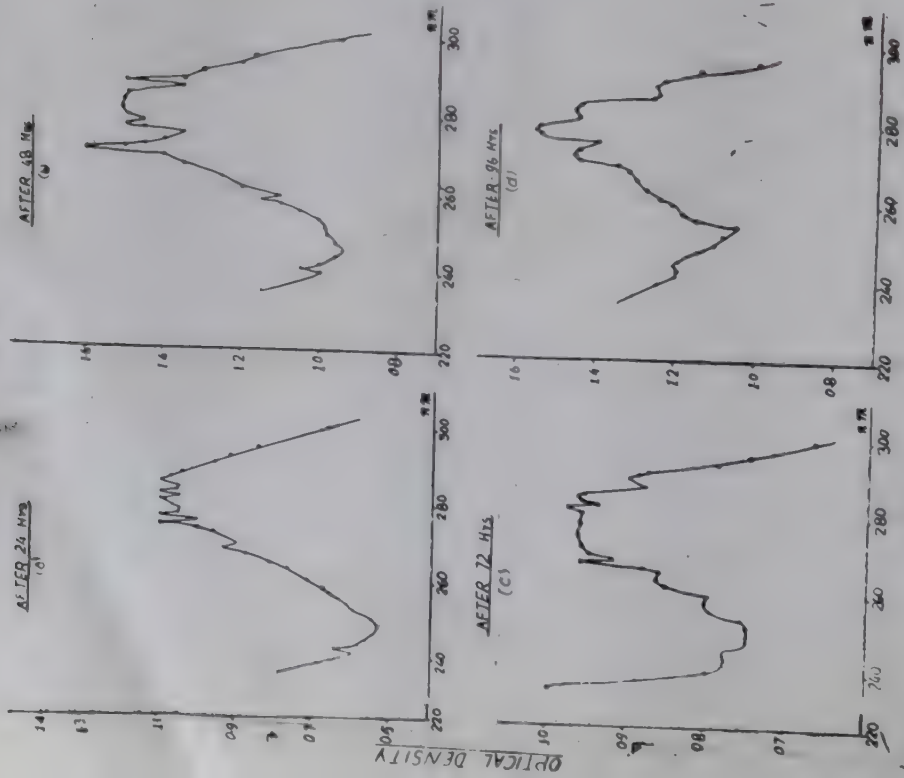


224 M. OF CARAMEL DIALYSIS 0.46 UNDER STIRRING
CONDITIONS AT DIFFERENT TIME INTERVALS



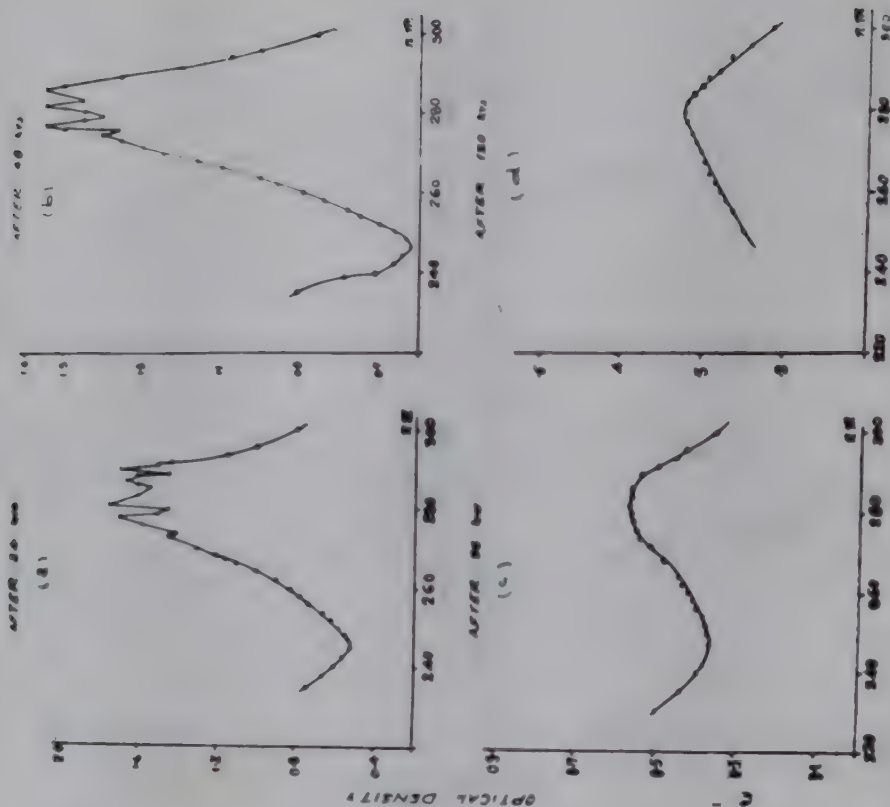
UV - SPECTRA OF CARAMEL DIALYSIS 0.46 UNDER STIRRING
CONDITIONS AT DIFFERENT TIME INTERVALS

FIG. 3



UV - SPECTRA OF CARAMEL DURING THE DIALYSIS WAS UNDER UNSTIRRED CONDITIONS AT DIFFERENT TIME INTERVALS

FIG. 4



UV - SPECTRA OF CARAMEL DIALYSING OUT UNDER UNSTIRRED CONDITIONS AT DIFFERENT TIME INTERVALS

THE EFFECTS OF YEAST-EXTRACT AND ION EXCHANGE TREATMENT OF MOLASSES ON KOJIC ACID PRODUCTION BY RESUSPENDED FUNGAL MYCELIA

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ABSTRACT

Earlier studies in our laboratory had shown that Indian cane molasses was more suitable for kojic acid production by *Aspergillus flavus* than for citric acid fermentation and it did not require any clarification. The addition of 1% yeast-extract to molasses solutions could enhance kojic acid production several folds in addition to reducing the fermentation period. It was also demonstrated that fungal mycelia grown in a yeast extract sucrose medium and resuspended in a simple phosphate buffer-sucrose medium were capable of producing large amount of kojic-acid.

In present study, employing stationary cultures of a locally isolated strain of *Aspergillus flavus*, the effect of 1% yeast extract on kojic acid production from ion-exchange resins treated and untreated molasses has been studied in growth and resuspension media. It has been observed that using 10° Brix untreated molasses solution, only 15% of the sugars were converted into kojic acid [7.5 mg/ml], whose yield could be raised to a practically three fold level by using the same molasses solution as resuspension medium [19.2 mg/ml, 38.5% yield] or by adding 1% yeast-extract to it and using as growth and fermentation medium [23.1 mg/ml, 46.2% yield]. It has also been revealed that neither the addition of salts like ammonium nitrate, dipotassium hydrogen phosphate and Magnesium sulphate to the untreated molasses solution nor treatment of molasses solution with ion-exchange resins [Duolite C-300 add A-100] or addition of yeast extract to the resuspension molasses media could increase the kojic acid yields further.

Introduction

Since recently, a lot of emphasis is being laid on proper utilization of by products of cane sugar industry viz. bagasse, molasses and press mud. Out of these greater attention has been paid to molasses on account of the large amounts of carbohydrates present therein and available for fermentation by various microorganisms. In addition to several direct and indirect uses, molasses in India is mainly used for fermentative production of ethyl-alcohol; however, its exploitation for production of industrially important products like food, pharmaceutical and bakers' yeast, citric acid, lactic acid, vitamins and amino acids etc. has been greatly hampered on account of deleterious effects of the impurities present in molasses on respective microorganisms^{1, 2}. We have quite recently reported the greater tolerance of kojic acid producing microorganism *Aspergillus flavus*, a fungus, to the organic and inorganic impurities present in cane molasses³. Although, kojic acid (5-hydroxy, 2-hydroxy-methyl-gamma-pyrone), a secondary metabolite of fungal origin, may not be included in the list of commercially important organic acids for the present, it has several potential uses in industry such as in tanning, insecticides⁴, fungicides⁵, antibiotics⁶, dyes, resins⁷, in preparation of metal chelates⁸ and as an analytical reagent especially for iron^{9, 10, 11, 12, 13}. In view of the foregoing it is very likely that kojic acid may attain industrial importance in near future. It was also revealed in our laboratory that kojic acid fermentation of molasses, using stationary cultures of *Aspergillus flavus*, did not require any clarification and that addition of small amounts of yeast extract to molasses solution could

markedly enhance the kojic acid production besides reducing the fermentation period¹⁴. We could also demonstrate that fungal mycelia grown in a yeast-extract sucrose (YES) medium and resuspended in a simple phosphate buffer sucrose medium were capable of producing large amounts of kojic acid¹⁵. In view of these findings it was interesting to investigate if addition of yeast extract to the molasses resuspension media could further enhance its stimulatory effect on kojic acid production in case of untreated and ion-exchange resin treated molasses solutions. Since Doelger and Prescott (1934) medium¹⁶ has been reported to favour citric acid production by *Aspergillus niger*, attempts were also made to enhance kojic acid production by supplementing molasses solutions with certain salts comprising the above mentioned medium.

Materials and Methods

All studies were done on a non-toxicogenic strain of *Aspergillus flavus* isolated in our laboratory and maintained by subculturing on potato dextrose agar slants at monthly intervals³. The methods regarding inoculation, treatment of molasses solutions, cultivation of the organism, fermentation conditions, assay of the kojic acid content etc. have previously been reported^{14, 15}. The general procedure followed was as below:—

The fungal spores were produced on potato dextrose agar medium and a predetermined inoculum size was aseptically inoculated into 50 ml aliquots of the medium, contained in 250 ml Erlenmeyer flasks. The flasks were incubated at 30°C and aliquots of fermentation medium were periodically removed and analysed for kojic acid content by the method

of Arnstein and Bentley^{8,7} using 1% ferric chloride reagent prepared in 0.1 N hydrochloric acid. To study the effect of salts contained in Doelger and Prescott (1934) medium¹⁶, NH_4NO_3 (2.23 g/l), K_2HPO_4 (10 g/l) and $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ (0.23 g/l) were added to the molasses solutions. Untreated vacuum pan sugarcane molasses diluted to 10, 20 and 30° Brix concentration was used as growth and fermentation media. For certain studies, 30° Brix molasses solution was first treated with a cation exchange resin (Duolite C-300), an anion exchange resin (Duolite A-100), and with both the resins before dilution to 10° Brix concentration⁴. To study the effect of 1% yeast extract on kojic acid production, it was added to different molasses solutions. For resuspension studies, the fungal mycelia were first grown in yeast extract-sucrose (YES) medium¹⁵ for 10 days, washed thrice with distilled water and resuspended again in different molasses solutions serving as fermentation media.

All experiments were done in duplicate and the average values have been reported here. Certified grade yeast extract was purchased from Difco and Co., U. S. A. The ion exchange resins, Duolite C-300 and A-100 were the products of Monte Cautic, Italy. All other chemicals were of highest purity grade available with British Drug House (India).

Results and Discussions

Different carbon sources varying from pentoses, hexoses, and disaccharides to polysaccharides and others have been used for kojic acid fermentation although best

yields have been reported to be obtained from glucose and xylose¹⁶. The optimum concentrations of carbon sources reported by different workers have also varied from 5 to 33 per cent^{19,20,21}. However, very little information is available on the fermentation of crude carbohydrate sources like cane juice, gur (jaggery) and molasses to kojic acid. Preliminary studies in our laboratory with a locally isolated strain of *Aspergillus flavus* have suggested its comparatively greater tolerance to the impurities present in cane molasses as compared to citric acid producing *Aspergillus niger* and that it could produce large quantities of kojic acid from unclarified molasses itself³. It was also observed that clarification of molasses by chemical or ion-exchange treatment methods could not further improve the kojic acid production. However, addition of 1% yeast-extract to the molasses media could increase the kojic acid production about three fold in addition to reducing the fermentation period by several days⁴. Further for understanding the mechanism of kojic acid synthesis it was considered necessary to develop a simple, chemically-defined resuspension medium. We could demonstrate that a fungal mycelium grown in yeast-extract sucrose (YES) medium could be successfully resuspended in a simple phosphate buffer medium containing sucrose or glucose and produce large amounts of kojic acid⁵. It was, therefore, tempting to study if a similar fungal mycelium grown in YES medium could be successfully resuspended in a molasses medium and still produce kojic acid, and that whether addition of 1% yeast extract to the molasses resuspension medium exerted the same stimulatory effect on kojic acid production as

reported earlier. Also, in a surface fermentation process, it is quite often that low nitrogen and high carbohydrate medium leads to higher production of secondary metabolites, e. g., YES medium gives high yields of aflatoxins²². The exact mechanism is not clear; however, this finding has several important implications for industrial fermentations. In view of the foregoing, the effect of yeast extract and certain salts of Doelger and Prescott (1934) medium¹⁶, generally employed for citric acid fermentation on kojic acid yields from molasses was also studied.

Table 1 exhibits the effect of salts and yeast-extract individually and jointly on kojic acid production by mycelia grown on untreated 10° Brix molasses solution. It may be noted that in control medium, i.e., 10° Brix molasses solution, very little kojic acid (7.5 mg/ml) was produced even after prolonged incubation (20 days). Upon adding a nitrogen-phosphate-magnesium-salt mixture, the maximum kojic acid production increased to 15.43 mg per ml. in fourteen days only. It is obvious, since addition of a nitrogen and phosphate source is likely to promote mycelial growth and discourage sporulation which could be favourable for kojic acid production since it has been reported that in case of *A. niger* large and thin mycelial mats and poor or no sporulation caused by low levels of nitrogen and phosphate have been observed to enhance citric acid production¹⁶. It is further revealed from table 1 that addition of 1% yeast extract to 10° Brix molasses solution enhanced kojic acid production still more to a value of 21.5 mg/ml. It is due to stimulatory effect of vitamins, minerals and other unidentified growth factors present in yeast-extract. How-

ever, when salts and 1% yeast extract were added together to the 10° Brix molasses solution a complimentary stimulatory effect was not observed and, on the contrary, kojic acid production decreased to 11.25 mg per ml only. This inhibitory effect might be due to high degree of sensitivity of yeast-extract stimulated kojic acid synthesizing enzyme systems to the salt levels added to the molasses solution. In view of above, it was considered desirable to add yeast extract alone to the molasses media in all subsequest studies.

The results of comparative studies on stimulatory effect of yeast-extract on kojic acid production using untreated molasses solution as a growth of resuspension media have been presented in table 2 and 3. It may be noted from table 2 that addition of 1% yeast-extract to untreated 10, 20 and 30° Brix molasses solutions used as growth media, caused a more than three-fold increase in maximum kojic acid production, enhancing the respective values from 7.5, 12.6 and 22.42 mg per ml. to 23.1, 40.02 and 80.02 mg per ml, respectively. However, this marked effect is not reproduced when 1% yeast extract is added to the same molasses solutions used as resuspension media. It may be revealed from table 3 that resuspension of fungal mycelia into untreated 10, 20 and 30° Brix molasses solutions caused an almost three times increase in maximum kojic acid production, changing the respective control values obtained in case of growth media from 7.5, 12.6 and 22.42 mg per ml, to 19.2, 42.41 and 72.02 mg/ml, respectively. It would also be observed from table 3 that unlike growth media, addition of 1% yeast extract to the resuspension media caused rather a slight decrease in maximum kojic acid production. Higher yields obtained in case of

resuspension media may be due to availability of more fermentable sugars for conversion of kojic acid which, in case of growth media were otherwise utilized for mycelial growth. The stimulatory effect of yeast-extract observed in case of growth media may be ascribed to the presence of vitamins, minerals, trace elements and other unidentified growth factors, promoting mycelial growth. However, it is difficult to predict any satisfactory reason for inhibitory effect of yeast extract in case of resuspension media. Possibly the level of growth stimulating factors present in the yeast extract hitherto un-utilized for promoting mycelial growth in case of resuspension media might have had some inhibitory effect on the kojic acid synthesizing enzyme systems.

Similar studies were performed to demonstrate the stimulatory effect of yeast extract on kojic acid production from 10° Brix molasses solution clarified by pretreatment with an anion exchange resin (Duolite A-100), a cation exchange resin (Duolite C-300) and with both the resins. The results have been presented in table 4 and 5, from which it is obvious that addition of yeast extract to these molasses solutions, used as growth and resuspension media not stimulate kojic acid production and instead decreases the maximum kojic acid yield practically in all such cases. The ion exchange treatment of molasses solutions used as growth media could not enhance kojic acid production; however, when the same solutions were used as resuspensions media, a two to two and a half-fold increase was observed (tables 4 and 5). This increase may be ascribed to the growth stimulatory effect of yeast extract present in YES medium which was used as growth medium for *A*

flavus mycelia later resuspended in ion exchange treated 10° Brix molasses solutions for kojic acid production. However, the inhibitory effect of yeast extract on kojic acid production in case of ion exchange resins treated molasses solutions may be assigned to the removal of certain ionic species present in molasses upon ion exchange resin treatment which might have had a stimulatory effect on kojic acid synthesizing enzyme system/s. It is difficult to predict any thing specific to the nature of such ionic species, however, they are likely to be more of anionic in nature since maximum kojic acid produced in case of anion exchange resin treated molasses solution (7.82 mg/ml) is almost half that produced in case of cation exchange resin treated molasses solution (13.7 mg/ml) and still lower in case of molasses solution treated with both the resins (7.45 mg/ml; table 4). It may be further observed that slightly lower yields of kojic acid were obtained in case of ion exchange resins treated molasses solutions used as resuspension media (19.26 mg/ml. table 3).

All above findings have been summarized in table 6 from which it is evident that while using 10° Brix untreated molasses solution as growth and fermentation medium, only 15% of sugars are converted into kojic acid, which may be raised to a practically threefold level either by using the same molasses solution as resuspension media (38.5%) or by adding 1% yeast extract to it and using as growth and fermentation medium (46.2%). It may also be revealed from table 6 that treatment of molasses solutions with ion exchange resins or addition of yeast extract to the resuspension media could not enhance the kojic acid yield further.

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Table—1

Effect of Salts* and Yeast-Extract on Kojic Acid Production From Untreated Molasses Solution Used as Growth and Fermentation Medium.

Sl. No.	Treatment	Kojic acid produced (mg/ml Period of Incubation (days))					
		3	6	9	11	14	20
1.	10° Brix untreated molasses solution (control)	1.82	2.40	3.02	4.72	6.10	7.50
2.	„ + 1% yeast extract	8.81	12.61	14.02	15.62	21.50	6.32
3.	„ + salts*	5.56	6.82	8.12	10.92	15.43	4.12
4.	„ + „ 1% yeast extract	4.12	5.06	5.56	7.02	11.25	3.05

* As mentioned in the text.

Table—2

**Effect of Yeast Extract on Kojic Acid Production For Untreated Molasses
Solution Used as Growth and Fermentation Medium**

Sl. No.	Treatent	Kojic acsd produced (mg/ml) Period of Incubation (days)					
		3	6	9	11	14	20
1.	10° Brix molasses solution	1.82	2.40	3.02	4.72	6.10	7.50
2.	„ + 1% yeast extract	9.52	15.20	16.02	17.21	23.10	7.15
3.	20° Brix molasses solution.	2.15	3.55	4.55	7.02	8.25	12.60
4.	„ + 1% yeast extract	16.40	22.41	25.20	25.92	40.02	26.82
5.	30° Brix molasscs solution.	very little growth	10.81	11.80	12.70	20.02	22.42
6.	„ + 1% yeast extract	„	33.80	35.40	73.21	80.02	35.60

Table—3

**Effect of Yeast Extract on Kojic Acid Production From Untreated Molasses
Solution Used as Resuspension Medium**

Sl. No.	Treatment	Kojic acid produced (mg/ml.) Period of Incubation (days)					
		1	3	5	7	9	11
1.	10° Brix molasses solution	8.60	12.20	<u>19.26</u>	11.86	4.28	2.20
2.	„ + 1% yeast extract	10.60	11.65	<u>11.95</u>	5.02	0.55	0.24
3.	20° Brix molasses solution	6.50	25.20	39.92	<u>42.41</u>	10.81	5.10
4.	„ + 1% yeast extract	7.60	13.52	<u>36.29</u>	36.02	2.81	1.20
5.	30° Brix molasses solution	7.02	8.70	29.20	55.21	<u>72.02</u>	32.04
6.	„ + 1% yeast extract.	9.60	10.02	19.21	40.04	62.41	26.02

Table-4

Effect of Yeast Extract on Kojic Acid Production From ion Exchange Resins
Treated Molasses Solutions Used as Growth and Fermentation Medium

Sl. No.	Treatment	Kojic acid produced (mg/ml.) Period of Incubation (days)								
		3	6	9	12	16	18	20	24	28
1.	10° Brix molasses solution treated with anion exchange resin.	2.48	2.72	3.55	4.26	6.0	5.04	5.46	6.67	7.82
2.	„ + 1% yeast extract	6.92	8.62	5.35	3.12	3.05	2.55	1.12	—	—
3.	10° Brix molasses solution treated with cation exchange resin.	1.40	1.85	2.72	3.55	—	6.30	7.45	9.73	13.70
4.	„ + 1% yeast extract.	7.70	9.21	4.65	1.72	1.50	1.15	0.75	—	—
5.	10° Brix molasses solution treated with anion and cation exchange resins	0.55	1.03	1.39	1.79	—	3.08	3.52	5.53	7.45
6.	„ + 1% yeast extract.	8.85	18.82	18.35	8.36	8.12	3.92	1.95	—	—

Table—5

**Effect of Yeast Dxttract on Kojic Acid ProDUCTION Erom Ion Exchange Resins
Treated Molassessolutions Used as Resuspension Medium.**

Sl.	Treatment	Kojic acid produced (mg/ml.) Period of Incubation (days)					

1.	10° Brix molasses solution treated with anion exchange resins.	2.40	8.10	13.92	15.72	<u>16.30</u>	3.92
2.	„ + 1% yeast extract	2.50	10.60	9.62	2.65	2.42	1.55
3.	10° Brix molasses solution with cation exchange resin	4.30	10.42	15.82	16.92	14.60	12.02
4.	„ + 1% yeast extract	5.02	12.41	7.42	0.42	0.15	0.11
5.	10° Brix molasses solution treated with anion and cation exchange resins.	1.40	6.20	8.41	10.40	18.92	12.60
6.	„ + 1% yeast extract	1.02	7.12	8.32	14.72	18.82	14.42

Table-6

Effect of salts and Yeast-Extract on substrate product conversion Efficiency.

Sl. No.	Treatments	Substrate product conversion efficiency in case of use as			
		Growth and fermentation medium.		Resuspension medium.	
		As maximum kojic acid produced (mg/ml)	As percent yield	As maximum kojic acid produced (mg/ml)	As percent yield
1.	10° Brix untreated molasses solution (control)	7.50	15.0	—	—
2.	„ + 1% yeast extract	21.5	43.0	—	—
3.	„ + salts	15.43	30.8	—	—
4.	„ + salts** + 1% yeast extract	11.25	22.5	—	—
5.	Untreated molasses solution— 10° Brix molasses solution	7.50	15.0	19.26	38.5
6.	„ + 1% yeast extract	23.10	46.2	11.95	23.9
7.	20° Brix molasses solution	12.6	12.6	42.41	42.41
8.	„ + 1% yeast extract	40.02	40.02	30.29	36.29
9.	30° Brix molasses solution	22.42	14.60	72.02	48.0
10.	„ + 1% yeast extract	80.02	53.30	62.41	41.60
11.	10° Brix molasses solution treated with anion exchange resin	7.82	15.60	46.30	32.6

(Contd.)

G 166

42nd Convention 1978

12.	„ + 1% yeast extract	8.62	17.20	10.60	21.20
13	„ Treated with cation exchange resin.	13.70	27.40	16.92	33.80
14.	„ + 1% yeast extract	9.21	18.0	12.41	24.80
15.	„ Treated with anion and cation exchange resins.	7.45	14.90	18.92	37.8
16.	„ + 1% yeast extract	18.82	37.60	18.82	37.6

* based on initial sugar present in medium.

** as mentioned in the text.

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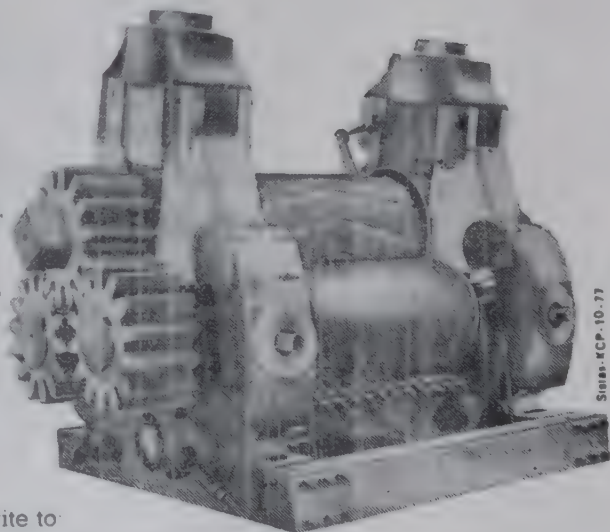
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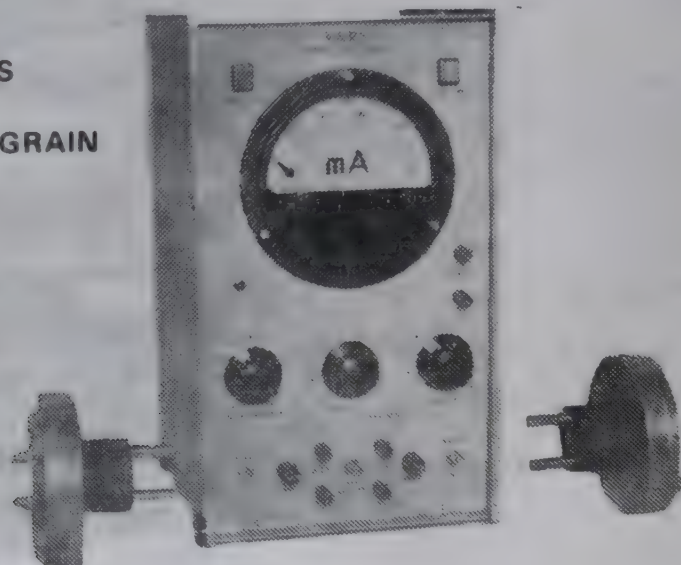
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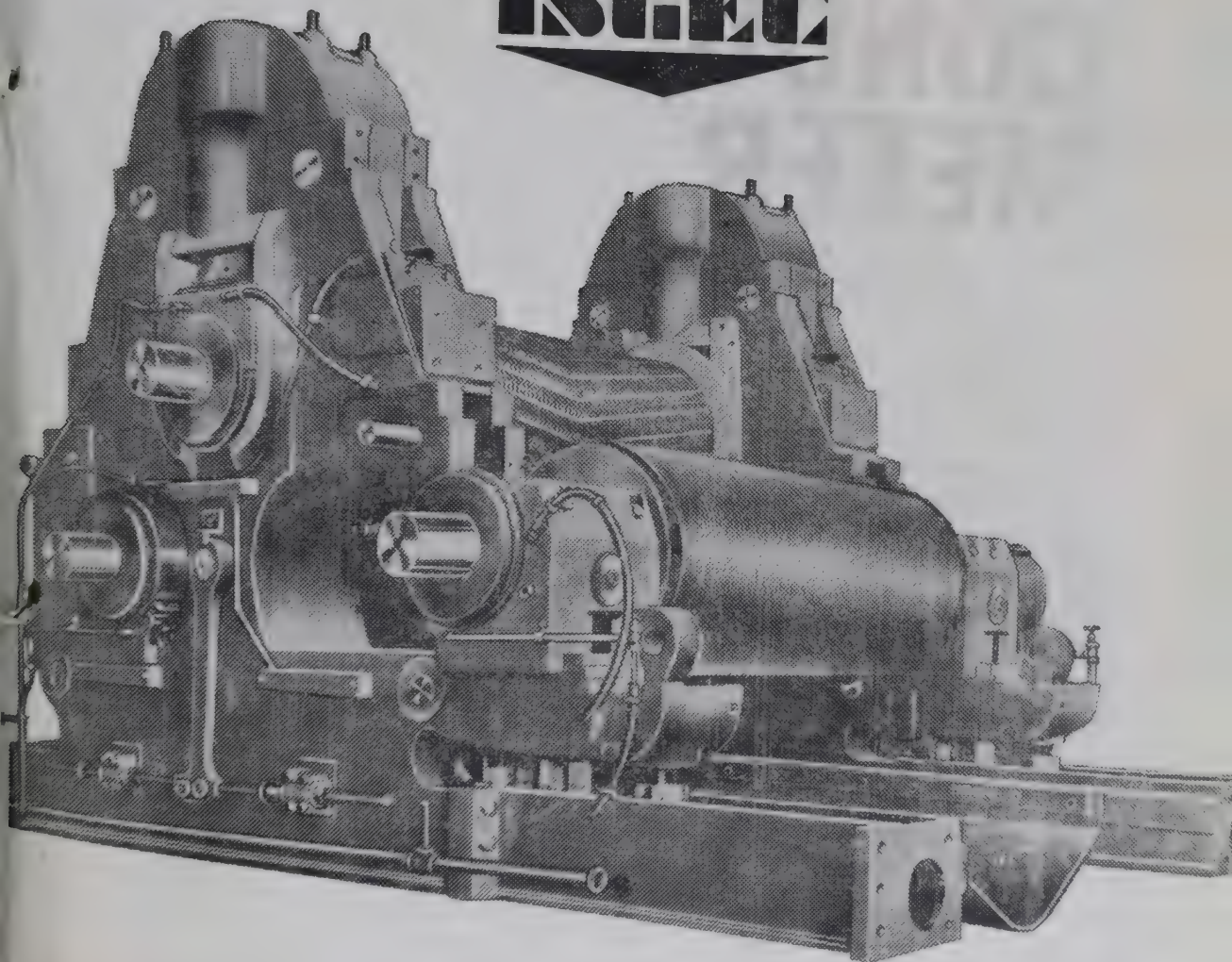
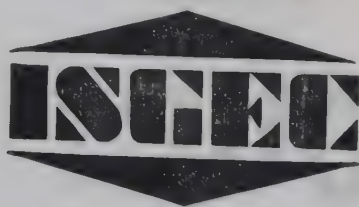
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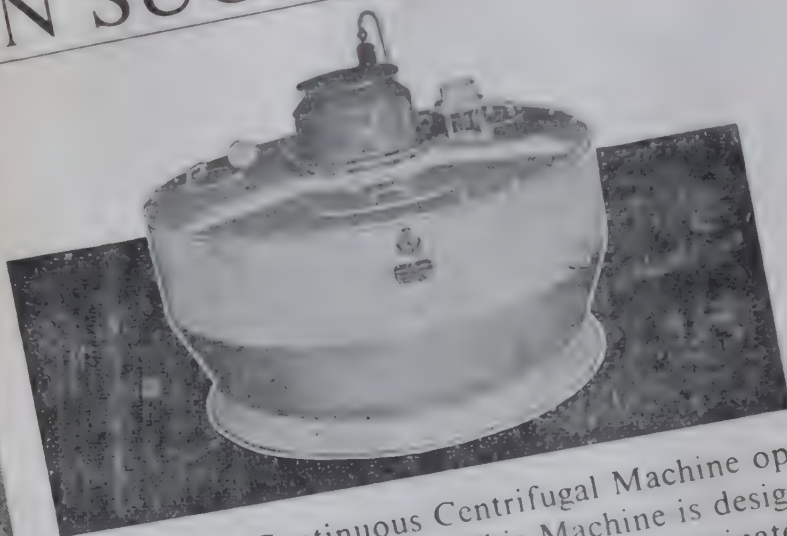
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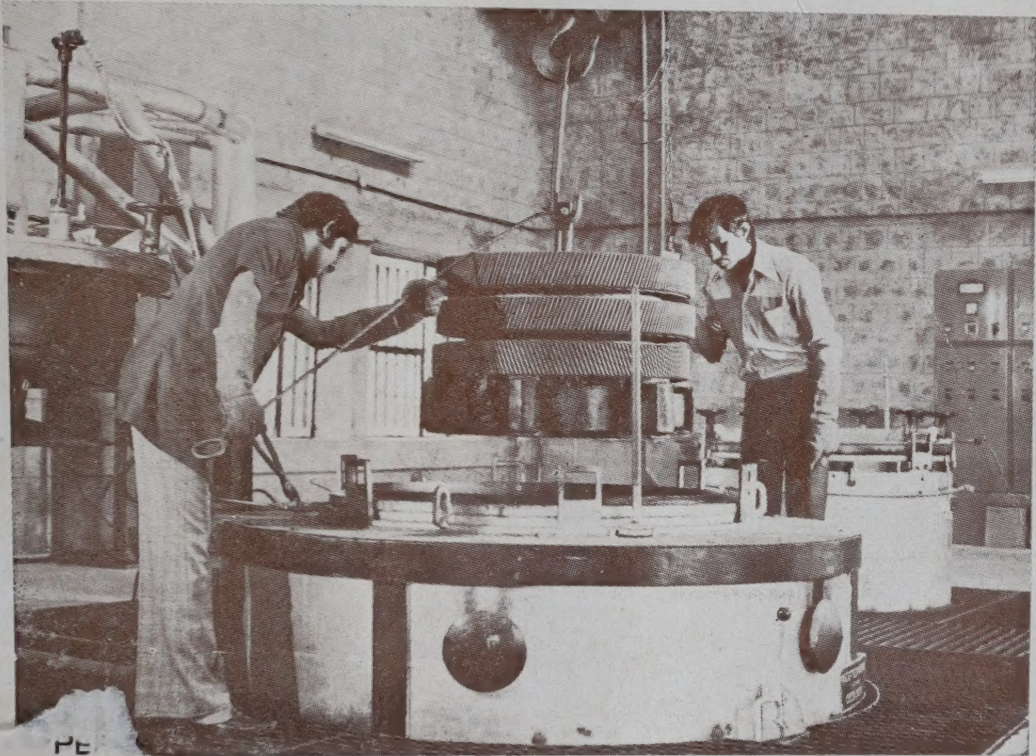
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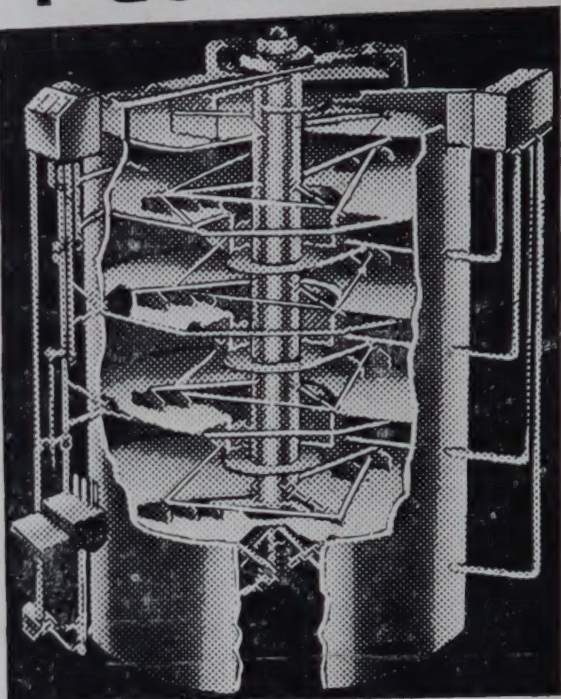
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